THE

JOURNAL

OF

THE AMERICAN SOCIETY
OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

MID-OCTOBER 1908

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CONTENTS

Society Affairs 3
November Meeting. Annual Meeting. Forward Work. Committee on Engineering Education. Personals.
Society History 1201
Papers for the December Meeting
The Engineer and the People, M. L. Cooke 1205
Liquid Tachometers, Amasa Trowbridge 1215
A Method of Obtaining Ratios of Specific Heats of Vapors, A. R. Dodge 1227
An Averaging Instrument for Polar Diagrams, W. F. Durand 1241
The Slipping Point of Rolled Boiler Tube Joints, O. P. Hood 1247
Possibilities of the Gasolene Turbine, F. C. Wagner 1261
Salt Manufacture, Geo. E. Willcox 1273
Discussion
Hoisting and Conveying Machinery. The Author 1291
Continuous Conveying of Materials. The Author 1291
Conveying Machinery in a Cement Plant. The Author 1294
The By-Product Coke Oven. The Author 1297
Rational Method of Checking Conical Pistons for Stress. The Author... 1299
Economy Tests of High Speed Engines. The Authors 1300
Comparison of Screw Thread Standards. The Author 1300
New Books 1301
Acquisitions to Library 1303
Employment Bulletin 1305
Changes in Membership 1308
Coming Meetings 1311
Officers and Committees 1315

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HISTORY OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Preliminary Report of the Committee on Society History

Chapter VI

THE DEVELOPMENT OF THE LIBRARY
(Continued)

161 At the Cincinnati meeting of the Society, in May 1890, announcement was made of the acquisition of the house at No. 12 West 31st St., New York, as a home for the Society, this being the building formerly occupied by The New York Academy of Medicine, and the hall of which had been for several years used by The American Society of Mechanical Engineers upon the occasion of its New York meetings. The plans for the acquirement of this property involved the incorporation of a new association, forming a sort of subsidiary body to hold the real estate, and the existence of the library afforded an advantageous opportunity of accomplishing the desired result in a very convenient manner.

162 The new corporation was called "The Mechanical Engineers' Library Association," this body being organized as a membership corporation under the laws of the State of New York relating to the conduct of free public libraries, the membership being divided into two classes, one, the Fellows, including all those who contributed regularly to the Library Fund, while the other, the Members, included all the members in the various grades of The American Society of Mechanical Engineers. The affairs of the Library Association were placed

Under the direction of the Council, the Committee on Society History has arranged to present the results of its investigations to the members of the Society. The Preliminary Report will appear in The Journal of the Society from month to month, and thus enable the matter to be open to comment during its completion. It is especially desired that any member who may be in the possession of facts or information bearing upon the various points as they are thus made public will communicate with the committee, in order that the final and completed report may have the advantage of the collaboration of the membership at large.

in the hands of a Board of nine Trustees, elected by the Fellows of the Association, these trustees having the management and control of the affairs, property, and funds of the Association, with full power to mortgage its real estate, and to issue bonds secured by mortgage thereon, and also to conduct the Library.

163 A charter was obtained for this Association on March 4, 1890, for the conduct of a Free Public Library containing a collection of books, charts, models, apparatus, and other literary and scientific works relating to the subject of Mechanical Engineering, so that the scope of the library was extended to include many things of historical value in addition to books, an extension which has led to the acquirement of numerous valuable relics which might have been dispersed, and possibly not preserved at all. The fundamental object of the Library Association, however, was to act as a holding corporation for the real estate which it was proposed to purchase for use as a home, both for the Library and for the Society. The Trustees, as originally selected, consisted of the Past-Presidents of the Society, together with the Secretary, the original Board including Messrs. Thurston, Leavitt, Sweet, Holloway, Sellers, Babcock, See, Hutton, and Towne; Mr. Henry R. Towne being chosen Chairman of the Board, a position which he held until the consolidation of the Association with The American Society of Mechanical Engineers, in 1907.

164 The Library Association having thus been incorporated, the purchase of the house in Thirty-first Street was concluded, the price being $60,000, of which $33,000 was left on first mortgage by the former owners, while the balance of $27,000 was paid in cash, this amount, together with the additional funds required for the repair and decoration of the building, being raised by the issuance and sale of bonds to the value of $31,800. These bonds were promptly taken by members of The American Society of Mechanical Engineers who were especially interested in the movement, and the matter was thus financed most successfully, a success which was largely due to the existence of the library and the Association incorporated in its name.

165 A portion of the building was let to the newly organized American Institute of Electrical Engineers, but the greater portion was occupied by The American Society of Mechanical Engineers, both societies being tenants of the holding corporation, The Mechanical Engineers' Library Association. Thus the library, from its modest beginning as a collection of trade catalogues and technical periodicals, became the means by which the Society was enabled to occupy

a most desirable building in one of the best locations in the city of New York, under conditions which at that time might not otherwise have been practicable.

166 The house, which had formerly been one of the fine old-fashioned brown stone residences, typical of New York home life, had been converted by the previous owners, the New York Academy of Medicine, into a building admirably suited for the needs of a professional organization. The front parlor had been left practically unchanged, but upon the garden plot in the rear there had been built a convenient meeting hall, this being two clear stories in height, with good basement room beneath, the hall communicating both with the back parlor and with the main entrance hall. The second floor rooms were fitted for the use of the library, while a balcony running entirely around the upper portion of the meeting hall added a corresponding amount of wall space to the shelf capacity. On the upper floors were convenient sleeping rooms for the use of members, in addition to the space originally let to the American Institute of Electrical Engineers, and subsequently added to the space available for the purposes of the Society.

167 Although the real estate was thus held in the name of The Mechanical Engineers Library Association, the books, etc., continued to be the property of The American Society of Mechanical Engineers, being loaned to the latter organization by the former as a part of the consideration passing between the two bodies in connection with the conduct of the building. The report of the Library Committee for 1890 showed a continual improvement both in the funds and in the collections, and it was evident that the library had become a most powerful auxiliary in the development of the Society.

168 When the house at No. 12 West 31st St. had been used by the New York Academy of Medicine, the walls of the meeting hall, as well as the other rooms had been covered with portraits of eminent members of the profession. Those members of The American Society of Mechanical Engineers who had been in the party which visited Europe in 1889 had also seen and appreciated the manner in which the homes of the great societies there were adorned with similar works of art. When the house in Thirty-first Street was first occupied by the Society, the barrenness of the bare walls contrasted painfully with the condition in which they had been seen at the previous meetings held in the same room, before the pictures belonging to the Academy of Medicine had been removed. There thus appeared a stimulus to the members to begin a similar collection of

portraits and works of art, to restore in some degree the effect which had formerly existed, and thus began the collection of paintings, photographs, etc., which now forms such an interesting portion of the property of the Society.

169 One of the earliest pictures thus acquired by the Society was an oil portrait of Alexander L. Holley, presented by Mrs. Bunker, formerly Mrs. Holley, a gift which was formally unveiled and accepted in an address by Dr. James C. Bayles. Other early acquisitions of this sort included a marble bust of Mr. Joseph Nason, presented by Mr. Carleton W. Nason; a portrait of Joseph Harrison, Jr., presented by Mrs. Harrison; a portrait of Professor Franz Reuleaux, presented by Mr. H. H. Suplee; a pastel of Professor W. J. M. Rankine, given by Professor F. R. Hutton, together with numerous photographs of interest. A notable gift of much historical value was the original autograph drawing by Robert Fulton of the "Fulton," the first steamer to ply on Long Island Sound, bearing the date 1813; while various old drawings and correspondence relating to the work of Fulton afterwards came into possession of the library. The portrait of Ericsson, by Ballin, was the one formerly owned by the designer of the Monitor, and was rescued from a curiosity shop where its value was hardly understood, and thus the interest of members grew continually in the development of this portion of the work of the library. Further acquisitions of this sort form an important portion of the records of the growth of the Society, and will be described at length hereafter in this history.

THE ENGINEER AND THE PEOPLE

A PLAN FOR A LARGER MEASURE OF COÖPERATION BETWEEN THE SOCIETY AND THE GENERAL PUBLIC

By Morris Llewellyn Cooke, Philadelphia, Pa.
Junior Member of the Society

In the work of the engineer there are three parties interested, i.e., the engineer, his employer and the public. While always recognizing the claim of this third party, engineers as a class have done little, directly, to satisfy it. The chief service rendered the public by the engineering profession has been one rendered indirectly by serving well the second party interested—the employer. It would appear that the time is near at hand when in matters in which they are specially qualified engineers must, individually and collectively, labor for the public interest with just as much fidelity and zeal as they work for their employer, and this not as public spirited citizens but rather as members of a public spirited profession.

2 If the standing of the engineering profession is to grow in the public esteem, it will be because of the effort of the profession to familiarize the public with its aims and ideals. If our own Society, representing the mechanical side of engineering practice, is to develop fully the possibilities of its field, it will be by utilizing every method of making its work of direct value to the people. Primarily this paper seeks to give some of the present day conditions which seem to demand a broadening of the lines of professional activity. A second object is to make a specific recommendation which, if adopted, it is believed will lead along a safe path to a stronger position for the mechanical engineer, considered as a member of the community. In this new

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The professional papers contained in The Journal are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present. They are issued to the members in confidence, and with the understanding that they are not to be published even in abstract, until after they have been presented at a meeting. All papers are subject to revision.

position the mechanical engineer will have placed at his command powerful forces at present denied to him and yet absolutely necessary for the full accomplishment of his professional mission.

THE ENGINEER AS A CONSERVATOR

3 There will probably be little protest against the conception of the engineer as the special conservator of the public interest in matters involving engineering. This view is certainly held by a majority of the leaders of the profession. The roll of our Society has always carried the names of scores of useful citizens who demonstrate in their lives their devotion to the public welfare. In the history of the Society many instances may be found where it has departed from the professional groove to coöperate in some broad way with a section of the general public. Our Society, through the activity of its distinguished President and Secretary, only interpreted the best thought of the membership in its recent valuable service to the National Government in connection with the work of the Conservation Congress and later with that of the Conservation Commission.

4 Granting this much, no one who gives the matter thought will be likely to contest the assertion that in the manifold activities of the Society and of the profession, the general public as such has been almost ignored. Among the announced committees of the Society not one has a title indicating a function broader than the conservation of the interests of engineering and of the engineering profession. Among the thousand and more papers listed in the last published index to Transactions, it is difficult to find a single title which indicates that the author was addressing any one beyond his professional audience. Inquiry among the lay public will show that while our Society is given full credit for its professional strength, absolutely no credit is given to it for interest in public matters. This is the public's estimate of technical organizations as a class.

THE OBJECT OF THE SOCIETY

5 The distinguished authors of the constitution of the Society stated its object in a way to permit of an almost indefinite expansion of function: "The object of the Society is to promote the arts and sciences connected with engineering and mechanical construction." That the constitution, however, imposes no duties on the membership except those of a purely professional interest, witness as follows: "The principal means for this purpose shall be the holding of meetings for

the reading and discussion of professional papers and for social intercourse; the publication and distribution of its papers and discussions; and the maintenance of an engineering library." The library may be made in the future to minister to the requirements of the layman interested in technical matters; but up to this time its direct influence on the great interests of the people has been almost negligible.

6 It can be granted for the sake of progress that the ideals of the engineering profession in this matter are sound. If it has been demonstrated that our practice does not square with these ideals, there appears to be good reason for taking action of some kind. It occurs to the writer that a radical, and in every way salutary, change can be brought about in the Society's relations with the general public by the appointment of a committee to be known as the "Committee on Relations with the Public." During the period required for amending the constitution to provide for such a Standing Committee, its work might be begun by a special committee appointed by action of the Council.

7 The work of a Committee on Relations with the Public would of course have to be done within carefully thought out and definitely prescribed limits. Even so, the work could be made very broad. The Committee would doubtless seek to establish such relations with the lay press as would make its advice and help sought when engineering matters are up for public discussion. It would also doubtless seek to give publicity to the fact that our Society stands ready to offer disinterested advice through its Council to government officials—municipal, state and national. In most cases, of course, this assistance would be not so much to answer engineering questions as to counsel with government officials as to the proper procedure to obtain answers. Such a relation now exists, for instance, between the federal Congress and the National Academy of Sciences. Under the Academy's charter the Congress has a right to call on it for help; and such assistance is at times requested. Such coöperation between governmental agencies and organizations belonging to the architectural profession is not at all uncommon, especially in foreign countries

POPULAR LECTURES ON ENGINEERING

8 A Committee on Relations with the Public might also provide for courses of lectures for the general public, to be given under the direct supervision of the committee in the Engineering Societies Building in New York, or under the auspices of local engineering societies

at other places. This committee might arrange with the Meetings Committee for at least one lecture on an engineering topic of general public interest at each Spring and Winter meeting, to which the general public would not only be invited but urged to attend. Another important part of the work of such a committee would be to arrange that a fair proportion of the professional papers presented at the various meetings of the Society should be of direct use and value to the public as well as to the mechanical engineer. The cumulative effect of these and of such other lines of work as would soon suggest themselves would be very marked. It is believed that through the work instituted by such a committee the mechanical engineer and the general public could be brought in a few years to a much better understanding.

9 Some members of the Society—especially among those engaged in the more abstruse branches of engineering—never having given much thought to this matter will doubt whether any part of the work of the mechanical engineer can be made of direct interest to the public. Of course, should the Society make coöperation with the public a definite part of its work, it is reasonable to suppose that lines of activity would be opened up which cannot now be foreseen. There is enough work in sight, however, to engage our attention for some time to come.

10 To illustrate: At the annual meeting in December 1905, our distinguished Past-President and present Honorary Councillor, John R. Freeman, delivered his presidential address "On the Safeguarding of Life in Theatres—A Study from the Standpoint of an Engineer." While the work, of which this address was a report, grew out of the Iroquois Theatre fire, it included a comprehensive study of all the great theatre fires during the past 100 years. The work was undertaken at the instance of a prominent manufacturer, two of whose nieces were among the nearly 600 victims of the Iroquois Theatre fire. This public spirited man wanted the investigation made "not for the purpose of fixing the blame but to help us find out how such fearful disasters can be prevented." Mr. Freeman's investigations covered every phase of the question, and in his report he made certain specific recommendations as to theatre construction and the prevention of fires in buildings of this class, such as would appear to reduce the liability to loss of life to a minimum. The recommendations were so logical and relatively so simple that if they could have been made of general public knowledge theatre owners and proprietors must almost inevitably have been forced by public opinion to their observance even if not impelled thereto of their own accord.

NECESSITY FOR MOLDING PUBLIC OPINION

11 Because this address had a professional interest for but a very small number of mechanical engineers it naturally received comparatively little notice in the technical press. Practically no notice was taken of it in the strictly lay press. Without a certain amount of publicity given to the results, an investigation of this kind might as well not have been undertaken. Mr. Freeman therefore had printed at private expense a few hundred copies of the paper and sent them to privately obtained lists of architects, building inspectors, fire marshals, theatre owners and proprietors, actors and actresses, editors of newspapers, mayors of cities, etc.

12 In the writer's opinion this kind of work should be done by the Society and can be better done by it. The Society should be so organized that matters of public interest may not only be investigated and reported, but that the reports may be given the requisite amount of publicity of the proper kind. Mr. Freeman's paper was filled with matter that almost any magazine or newspaper would have been glad to publish had it been properly shaped up for them when it was still "news." Abstracts of varying length might have been prepared by the editorial staff and published without cost in the lay press. This would have relieved the author of much work entirely outside his line, and not only have secured for the report a fuller measure of usefulness, but would have demonstrated to the public the breadth of our interests and work.

13 From its inception our Society has taken an advanced position in this matter of publicity. We are prohibited by our constitution from copyrighting papers read at our meetings, in order to facilitate their being reprinted in other publications. The constitution further says on this subject: "The policy shall be to give the professional and scientific papers read before it the widest circulation possible with the view of making the work of the Society known, encouraging engineering progress and extending the professional reputation of its members." The Society may some day change the rule which prevents the publication even of abstracts of papers before they are actually presented at meetings. It would seem policy for us to interest the public in as much of our work as can be made intelligible to the public.

THE MOMENTOUS CONSERVATION PROBLEM

14 The matter of the conservation of our national resources will afford probably for years a practically limitless field for investigation

and earnest discussion. The questions involved are so momentous as to warrant the engineer in seeking ways of coöperating with the National and State governments for their solution. No better way could be found for our Society to assist in this work than to provide in its meetings and publications a forum for the discussion of those phases of the general problem in which the mechanical engineer is specially qualified to speak. Many of these questions must be made clear to the layman because legislation will be required for their proper solution.

15 This further step in the line of coöperative engineering effort may seem to some of our members to be a radical one. But it appears to be only the logical sequence of those which have gone before. The records of engineering in the early days of the last century show that engineers had not then learned how to coöperate with each other. Up to a comparatively recent date the professional knowledge of an engineer was his own property and he felt that in imparting any of this knowledge to another engineer he was doing himself a decided injury. Discussions between engineers were carried on mainly with the object of doing each other harm rather than good. The large number of engineering societies, with the fundamental object of the free exchange of engineering data between their members, show how thoroughly engineers have learned that the general policy of giving freely of their knowledge to their fellow practitioners increases rather than diminishes their effectiveness and, in proportion, their earning power. In proposing the appointment of this new standing committee, the writer suggests only the extension of this coöperation to include the public. There is good reason to believe that engineers have as much to gain from coöperation with the public as they have undoubtedly gained from coöperation with each other.

A SECTION ON PUBLIC MATTERS

16 If the Society once expresses a desire to receive papers of interest alike to the engineer and the layman, the time will probably soon arrive when the increasing number of such papers will suggest the necessity for a Section on Public Matters. Such a section would be conducted like any other section of the Society and would promote and receive papers on subjects of special interest to the layman. These papers and the discussion on them would naturally have to be handled in a way to make them not only intelligible but of practical value to the layman. This work would naturally give rise from time

to time to broad practical summaries covering the essentials of good practice in fields where the general public is directly interested. These publications might easily become of the greatest value to legislators, national, state and municipal, on matters now generally settled without much professional advice or technical knowledge. Such a section would draw to its membership those members of the Society public spirited enough to be willing to devote some time to the investigation and discussion of technical matters in their application to the public interest. It would also probably attract as affiliates many of that rapidly increasing body of laymen who are giving freely of their time and money for the development of the best in the life of the whole people. The work of this section should be given a world-wide scope and interest.

THE AWAKENING IN THE MEDICAL PROFESSION

17 In considering the advisability of adopting the recommendation it is possible and beneficial to study the evolution of the same idea in the medical profession. Not so many years ago it would have been considered in many localities the height of unprofessional conduct for a physician to address any public gathering on a question relating to the public health. This viewpoint has gradually changed until it is almost impossible to pick up a newspaper without finding some evidence of the world-wide propaganda which the medical profession is carrying on for the education of the general public. The movement toward this change in viewpoint was materially assisted and quickened by the tuberculosis campaign. As soon as the medical profession discovered that this disease could probably be exterminated by simple scientific precautions it realized that its obvious duty was to explain this to the public. Under the old standards of professional etiquette this was impossible. So the old standards were changed.

18 In this movement it would be easy to underestimate the influence of the general public. It will be remembered that many of the first steps taken in the fight against the "white plague" were taken by laymen and by organizations made up largely of laymen. It was in a measure this activity of the laymen which forced the medical profession—the natural leaders in such a movement—to assume the lead.

19 Under the new code of ethics it is just as easy for a medical practitioner to discuss publicly the medical inspection of school chil-

dren, or the care of the insane, as to promote the crusade against consumption. For three or four years past the American Medical Association has had in the field a physician who travels over the country for the double purpose of talking to physicians on matters relating to the improvement of conditions in the medical profession and of lecturing to the public on questions of vital importance from a sanitary point of view. These lectures are well attended and are accomplishing much good. Last year the association created a Board of Public Instruction on Medical Subjects. While this Board has done much work it has really only formulated a preliminary scheme of operation. State and county organizations are encouraged to provide lectures, to enlist the interest of the newspaper press, and to watch and influence legislation, wherever it contributes to the welfare of the public.

THE MEDICAL AND CHIRURGICAL FACULTY, FOUNDED 1799

19 The result of this invitation to the local societies can be studied in the activities of almost any medical association. For instance, the Medical and Chirurgical Faculty, the representative medical association of the State of Maryland, an organization which dates its existence from 1799 and one of the most conservative bodies of scientific men to be found in the country, has now many committees solely engaged on matters of public concern. It maintains public lecture courses. It provides the newspaper press on request with signed and unsigned articles on any subject related to the public health. It has recently organized a state-wide campaign for bringing to the attention of the people and the legislature the necessity for a more liberal policy in the care of the insane.

20 As may be imagined, the change in professional attitude reflected by this widespread activity on behalf of the public was not brought about in a day or without powerful opposition. Indeed the writer is informed that some high minded practitioners of advanced years still feel that a mistaken policy is being followed. But the work of practically every medical association—national, state, county and city—indicates that the old conception of the duty of the profession to the public has been permanently abandoned. The president of the American Medical Association, Herbert L. Burrell, M.D., in his annual address of this year, devoted the major part to this subject, saying in conclusion: "A great duty rests on the practitioner of medicine today. He must not shirk it; he must rise to his new burden,

accept it and bear it. The reward to the medical profession for taking this new burden of judicious publicity in medicine will be a broader life for the practitioner, a greater consideration for his fellow man, better citizenship and the recognition by the world that the medical profession is a great public benefactor."

ASSISTANCE NEEDED IN EXPERIMENTAL WORK

21 As the range of human knowledge widens, the expense involved in carrying on the investigation and experimental work necessary to progress in such a profession as ours increases very rapidly. For the engineering profession to keep pace, for instance, with the progress being made today in medical science, our investigators and experimenters must have larger financial resources at their disposal than they have enjoyed in the past. Such foundations and bequests must come for the most part from those unconnected with the engineering profession and from those who put a value on the engineer's work for mankind. Such assistance will result only from a widespread appreciation of the engineer's achievements for the public good and of the requirements of engineering.

22 It is no longer possible for either a profession or a craft to corner information and hold it for its own use. Broadly speaking, those who seek information in any field can obtain it, or at least enough to answer their immediate purposes. And therein lies a danger. This danger would in itself constitute a sufficient reason for the engineer to take the public into his confidence. For after all it is public opinion and not the dictum of the engineering fraternity which finally decides the large questions of engineering practice. How much better it would be then to join forces with the people, to work out with the people the people's problems and to build up in the lay mind such a confidence in our devotion to the people's cause that they will be willing to let us lead in matters where our training especially qualifies us to do so. Only by educating the public to understand and appreciate the work of the engineer, can the public be made to demand the best that can be devised and executed by trained and skillful men. This will have a two-fold beneficial effect on the profession in that it will make more work for the engineer and will give the public that general acquaintance with engineering matters which will make it suspicious of short-cuts.

23 Dr. Hadley, in his address on "The Professional Ideals of the Twentieth Century," delivered at the opening of the Engineering Societies Building, spoke to the engineering profession as follows:

> Yours is the proud boast of having in one brief century established science as the arbiter of the material affairs of mankind, and of having enforced her worship upon a world once reluctant but now gloriously admiring.
>
> Well then, you will ask: Is there anything which remains to be done comparable in importance to this? Yes, there is. An equally large part; perhaps in one sense, a much larger part of your professional duty yet remains to be accomplished. It is not enough to have technical training. It is not enough to know the special sciences on which the practice of a profession is based. A man ought to have a clear conception of the public service on which his profession is based; a man ought to have clear conception of the public service which his profession can render and the public duty which its members owe. Thus, and thus only, can the engineer, the lawyer, the physician or a member of any other learned profession rise to the full dignity of his calling.

BROADER TENDENCIES OF THE DAY

24 There may be some who feel that in launching a movement of the kind proposed the Society would run the risk of getting into difficult positions and even of antagonizing friendly interests. Judging from what is going on around us in this Republic today, and in fact throughout the world, a step of this kind will commend itself so powerfully to the public as to bring to our standard a hundred friends for every one we could possibly lose. However, were this not so there is no sacrifice which the profession ought not to be glad to make to put itself in line with the most advanced ideas of public service. For after all the greatest value to come out of the broader activities is the inspiration to the individual engineer in his everyday work from this closer association with that great employer, the people, for whom in the last analysis all ultimately useful work is done.

LIQUID TACHOMETERS

OPERATION, CONSTRUCTION AND METHOD OF TESTING

By Amasa Trowbridge, Hartford, Conn.

Member of the Society

In any instrument designed for measuring the speed of a revolving wheel or shaft, the centrifugal force developed by the revolution of some part of the measuring instrument is almost universally used to give the indications. This centrifugal force should be so applied as to eliminate, as far as possible, the errors due to friction or wear. This cannot be attained by the use of a solid body as the flying balls in a ball governor, or the moving weights of a shaft governor. The Veeder Tachometer, described in this paper, makes use of a liquid in a device similar to a centrifugal pump. By careful experiments extending over nearly eight years several forms embodying this principle have been perfected. As the paddle of the pump does not touch the case in which it revolves, there is no wear between the revolving paddle and stationary case. The bearings are so constructed that the wear is slight and does not affect the readings. The liquid does not change its character appreciably under any circumstances and consequently, the indications of the instrument will be correct after it has once been properly graduated.

2 The principle on which the liquid tachometer acts is, that the pressure developed by the centrifugal force of the liquid, when the instrument is running at a certain speed, is a definite quantity. This pressure forces liquid up the indicating tube A, Fig. 1, and is balanced by the pressure due to the height of the column of liquid in the tube.

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3 Referring to the formula for centrifugal force which is, $F = \frac{Wv^2}{r\,g}$, we notice in this formula that there is but one variable, when r, the radius of the paddle, and W, the weight of the liquid, are fixed. Hence the indications of the instrument depend entirely on the velocity and do not change if wear is eliminated. The friction of the pump, generally speaking, need not be considered, nor its efficiency. If there be no flow of the liquid, the force F is expended in maintaining a pressure P and this is equal to the pressure Wh due to the height of the liquid column. When the column is at rest, that is, when the speed is constant, F equals P, hence $\frac{Wv^2}{r\,g} = Wh$. It is obvious from this that W may be varied at will without materially affecting the height of the column. This is found to be the case and it makes little difference in a liquid tachometer whether the liquid employed be something heavy like mercury, or light as alcohol. The indications are essentially the same for both liquids.

4 It is of course highly important that a suitable liquid should be chosen for such an instrument. In the first place it is necessary to choose a liquid which will not freeze at any temperature commonly encountered. It should be also as safe as possible in regard to fire, because it may frequently be used in the neighborhood of an internal combustion engine, where inflammable vapors would be dangerous if allowed to escape. Also it should be readily obtainable; and such that its viscosity will not be materially altered by the ordinary change of temperature. The viscosity of the liquid makes a slight difference in the height of the indicating column.

EFFECT OF VISCOSITY ON REVOLUTIONS REQUIRED

Material	Kerosene	Water	Alcohol	Benzine	Sperm Oil	Paraffin Oil	Valvoline Oil No. 2	Glycerin
Revolutions Required	852	851	850	849	807	792	788	779

5 A series of experiments was conducted to determine the relative viscosities of various liquids. The more commonly used liquids were tested in the following manner: An instrument having a long tube was put on the testing machine filled with one liquid and run at such speed as to give a fixed height of column. The first liquid tested being alcohol, a height of column corresponding to 850 r.p.m. was taken. The other liquids were each in turn put into the same instrument and the revolutions of the instrument required to maintain the same height of column were taken, as shown in above table.

6 It is surprising to find that benzine is more viscous than kerosene. Experiments are still being conducted on this point, the results of which are not ready for publication. Other points which must be

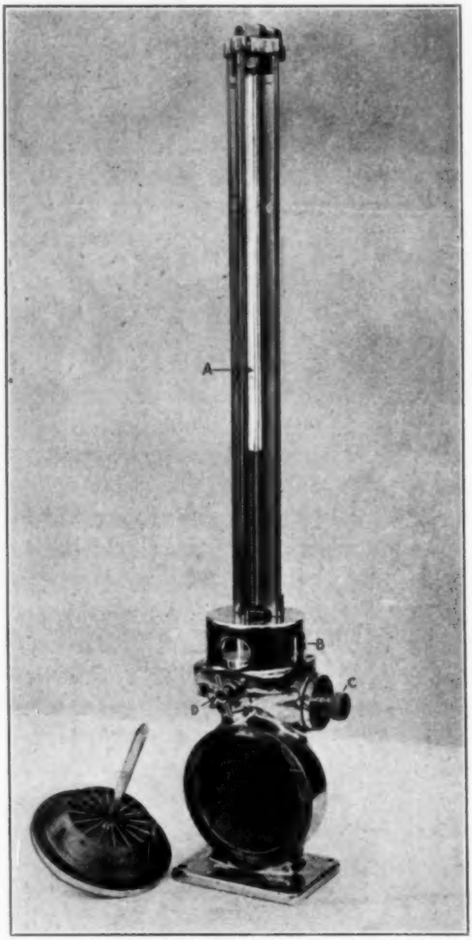

Fig. 1 The Veeder Liquid Tachometer

considered are the lubricating qualities of the liquid and its liability to corrode the metal of which the instrument is made.

7 The Veeder Tachometer, in one of its present forms, is shown in Fig. 1, with paddle removed. This instrument embodies all of the

necessary points enumerated above. The only moving part of the instrument is the paddle which imparts the necessary centrifugal force to the liquid contained in the body of the instrument. A small reservoir B is located directly above the paddle case. In the center of this reservoir is a glass tube through which the liquid flows to the glass indicating tube A. A suitable zero mark is provided around this small tube in the center of the reservoir. The liquid rises by capillary attraction in this small central tube somewhat above the level of the liquid in the reservoir. This enables the instrument to be set at zero very handily, a displacement plug operated by a small thumb nut shown at C enabling the operator to raise or lower the height of the surface of the liquid to exactly the zero mark. The glass indicating tube is about 12 in. high, although a scale fully 3 ft. high can be used where extreme accuracy is necessary.

8 Free passage is provided from the reservoir to the center of the paddle wheel, allowing the liquid to flow freely to the paddle wheel, from which it is thrown out through very small orifices in the periphery of the paddle case. At the front of the instrument is a small handle D, which operates a valve to choke the passage from the pump to the indicating column. This prevents the dancing or vibration of the liquid column, due to any sudden fluctuation in the speed of the revolving body whose revolutions are being indicated. The liquid used in this instrument is alcohol colored with an aniline dye. This liquid has been found extremely satisfactory, although other liquids may be used in place of it for certain cases.

9 It is evident that the graduations in this instrument will not be evenly spaced from zero up to the maximum. The height of the liquid column depends on the centrifugal force which varies with the square of the speed of the paddle; hence, the graduations will be more open at the top of the scale for the high speeds, than at the bottom where the low speeds are measured. This is an advantage in some ways, especially on automobiles, since the graduations are large at high speeds when the vibration is greatest. Of course it necessitates a number of different instruments to cover the ordinary ranges of speed because the readings from zero up to about one-third of the maximum reading of the instrument are of no value, the graduations being so close that they are entirely omitted.

10 The liquid is admitted to the paddle case from the reservoir by passages on both sides. When the liquid is admitted from one side only, a slight change in the position of the paddle axially makes a change in the indications. This is not found to be the case where the balanced admission opening is used.

11 The blades of the paddle are radial, for the purpose of making the instrument reversible. The radial blade is of course not the most efficient but, as stated above, the efficiency need not be considered. A ball thrust bearing is provided for the paddle shaft, thus eliminating any wear that would prove injurious.

12 The outlet for the liquid consists of a number of small radial holes, equally spaced around the periphery of the paddle case. With a single discharge opening it is found that if through wear of the bearings the paddle becomes eccentric with the case, then reversing the instrument changes the indications. The diameter of these outlet holes is very small, to check any surging of the liquid. They discharge into an annular groove extending around the paddle case, and this annular groove is connected by a single hole to the indicating tube.

13 One of the greatest difficulties encountered in making this instrument has been to get the entrained air out of the liquid. The small passages used in the pressure side offer little opportunity for it to escape, hence it stays in the paddle case. The trouble has been eliminated by so shaping the paddle that as soon as the paddle revolves this air is forced to the center of the paddle and is discharged through the center openings. If the air is allowed to stay in the paddle case it furnishes a compressible cushion for the column of liquid, and materially reduces the effective area of the blades, especially in the small diameter paddles. A slight change in the temperature of this air also affects its density to such an extent as to alter the reading of the instrument. Some instruments having glass sides were built for the purpose of studying the action of this air to determine ways for eliminating it.

14 The sensitiveness of the instrument is such that at the maximum speed for which it has been made commercially, namely 2500 r.p.m., a difference of one or two revolutions is very noticeable. This shows that the instrument can be made to indicate within less than one-tenth of one per cent. Under ordinary circumstances the indications will be correct within one-fourth of one per cent.

15 The instrument is portable, and can be readily handled, and there is no difficulty in holding the column practically vertical. It may be used either by holding it in the hand, the paddle wheel shaft being driven by a short flexible shaft pressed against the end of the revolving member whose revolutions are to be measured, or it may be fastened down and driven by gears, as in Fig. 3. This latter is the preferable method because the instrument is then held very steadily,

and the entire attention of the operator can be given to reading the indications.

16 To carry on the experiments for these instruments, Mr. Veeder built the testing machine shown in Fig. 2 and 3. This testing machine is run by an alternating current motor used exclusively for this pur-

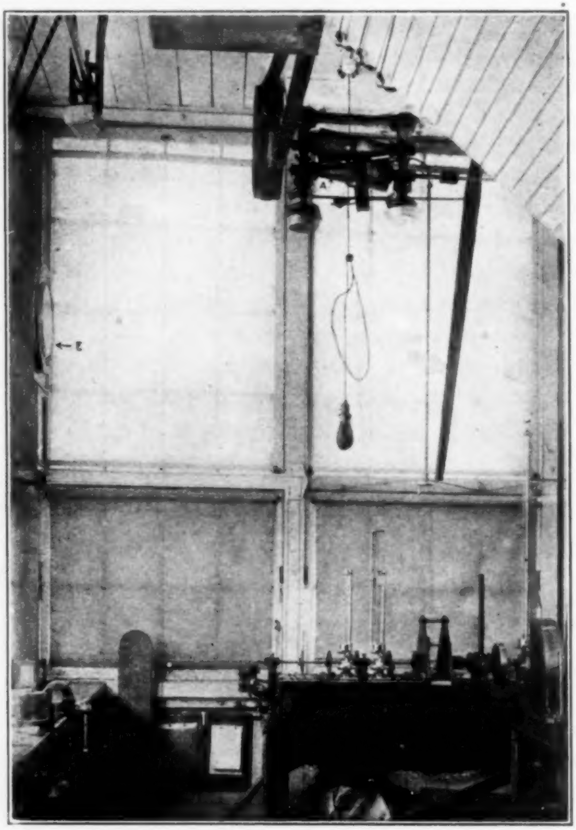

FIG. 2 TESTING MACHINE

pose. The motor is connected to the testing machine through an Evans Friction Cone, *A* in Fig. 2, which gives a ready means of changing the speed of the machine through a certain limited range.

17 To keep the speed of the testing machine constant, a mercury tachometer *B*, Fig. 3, having a tube about 3 ft. high, is placed at the driving end of the machine. This tachometer controls an electrically

operated brake which bears againstva the periphery of the hey fly-wheel as shown at C in Fig. 3. Because the inertia of this wheel is very great in proportion to the force applied by the brake, there are no sudden fluctuations of speed. The mercury tachometer is an extremely delicate instrument and either makes or breaks the circuit which operates the friction brake. An insulated rod is carried through the top of it and connected, as shown by the diagram, Fig. 4, to the brake magnet. By adjusting the vertical rod, the tachometer will control the testing machine through a considerable range of speed.

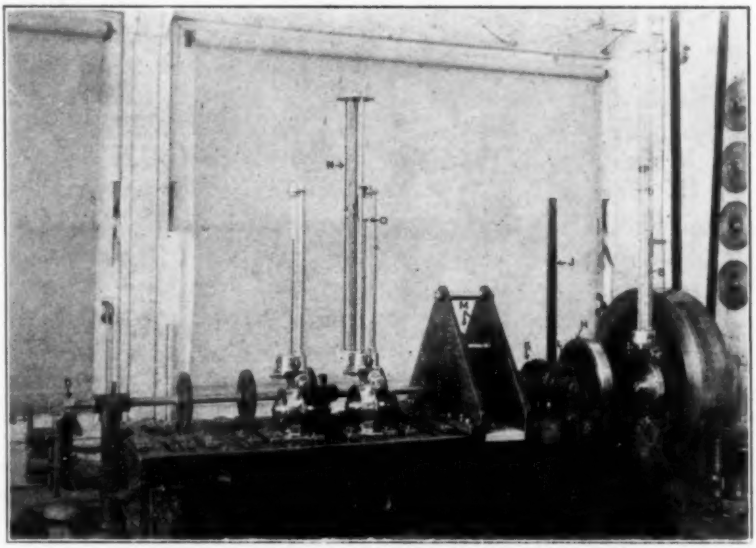

Fig. 3 Testing Machine, with Paddle Wheel Shaft Driven by Gears

The action of the brake is clearly shown in the diagram. A condenser is used to avoid oxidation of the mercury at the point of contact.

18 To check the testing machine the shaft of the machine is connected to a revolution counter as shown at D, Fig. 3. The connection between this counter and the shaft is automatically made at the beginning of a minute by the master clock, E, Fig. 2. At the end of a minute, this connection is automatically broken by the same clock, and the difference in indications of the counter shows the number of revolutions made by the shaft of the testing machine in the minute.

Slight changes in the speed of the spindle of the testing machine will of course be very evident from this method of checking.

19 The diagram, Fig. 5, shows the method of connecting the clock to the revolution counter which is driven by the end of the shaft of the testing machine. Special attention is called to the fact that the connection is made by the clock for one single beat, or half period, of the pendulum only; that is, while the pendulum swings

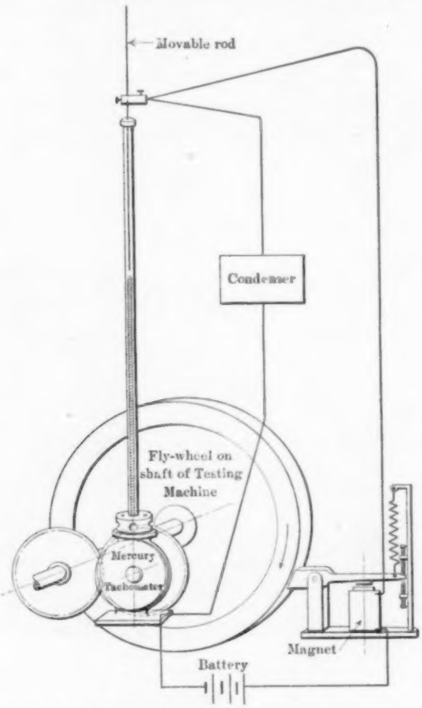

FIG. 4 AUTOMATIC SPEED CONTROLLER FOR TESTING MACHINE

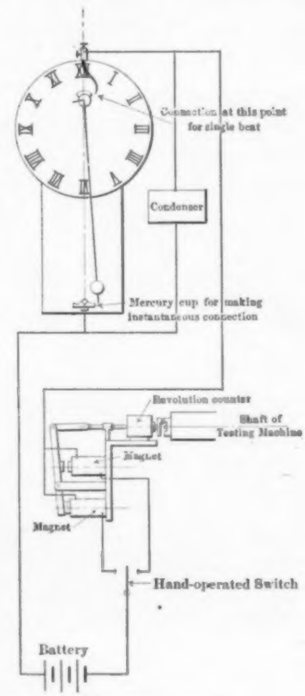

FIG 5 CONNECTIONS FOR SPEED COUNTER

from left to right. This necessitates that the time during which there is a complete circuit is a small fraction of a second, namely, while the point of the pendulum passes through the mercury cup at the middle of the clock, hence at that point which the pendulum passes with its greatest velocity. This arrangement determines that exactly one minute shall be the time between the throwing in of the revolution counter and its disconnection. It was also found necessary to insert a condenser in this electric circuit for the purpose of preventing an arc, as in the case of the mercury tachometer.

20 At F, Fig. 3, there is seen the hand switch by which the circuit is made ready for the clock to throw the revolution counter into or out of gear. By throwing the switch one way the clock will throw the counter into gear. If thrown over on to the other side, the counter is thrown out of gear at the end of that minute. By using this hand switch it is possible to make the count extend over as many minutes as may be desired. The shaft of the revolution counter is carried by the lever G, Fig. 3, and has on its end a key which engages positively in one of a number of slots on the end of the testing machine shaft. This counter has been safely operated at as high a speed as 5000 r.p.m., and this method of registering is such that it is absolutely reliable.

21 In Fig. 3 there is shown at H a friction clutch, the outer part of which is driven by the fly-wheel shaft. Between the bevel gears K and L is a jaw clutch, keyed to the shaft carrying the inner part of the friction clutch. This is operated by the lever J. The first part of the motion of the lever engages the jaw clutch with one or the other of the beveled gears. Its remaining throw engages the friction clutch. By throwing the lever one way or the other, the direction of rotation of the main shaft of the machine may be changed.

22 For calibrating any particular instrument, the fly-wheel end of the shaft is operated at a constant speed, usually 1,000 r.p.m. Under ordinary circumstances, with a speed of 1,000 r.p.m. the variation will be less than half a revolution either way from the standard. With special care, this can be reduced to $\frac{1}{4}$ of a revolution, or a total variation of one-twentieth of one per cent. This speed is transmitted to that part of the shaft which directly drives the instruments through the back-gearing shown at M. By means of the changes accomplished by these back-gears, the speed of the fly-wheel need not be changed during the calibration of the instrument.

23 The device shown at N in Fig. 3 is used for calibrating the instruments. The screw in this device has a very accurately cut thread with 14 threads to the inch. At the top of the device is seen a plate with 100 graduations equally spaced. From this it is seen that a vertical adjustment of the sighting piece shown at O, Fig. 3, amounting to about 0.0007 in. can be measured.

24 A number of instruments of a given size are set on the testing machine at once. The height of the liquid column in these instruments is then measured, a record being kept for each instrument. The average of these readings is then taken for establishing a suitable scale to be used on instruments of that size. The calibrating device is removable and can be shifted from instrument to instrument with-

out changing its setting. In this way very small variations in the different instruments can be noted and any errors due to bad workmanship or imperfections in the parts can be readily detected.

25 Among the many applications to which this tachometer has been adapted, the first has been for laboratory service in testing dynamos, engines and other machines having revolving members. The instruments have also been adapted for switchboards, grouped with the other instruments. Here they give a continuous indication of the r.p.m. of either the engine or generator.

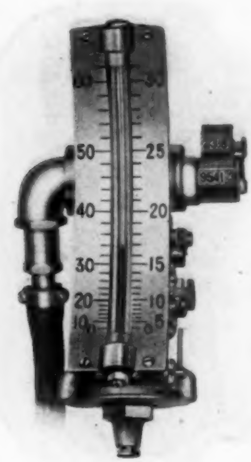

Fig. 6 Form of Tachometer for Automobile Service

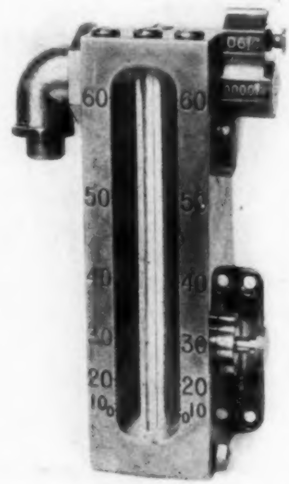

Fig. 7 Form of Tachometer for Railroad Service

26 Another use to which these instruments have been adapted is as a speed indicator for automobile and locomotive service. The type commonly used on automobiles, shown in Fig. 6, has a double paddle, the larger diameter used for low speeds, the smaller for high. To make use of this a double scale is put on the instrument, one reading to about 30 miles per hour, the other twice as high, and the instrument is arranged to use either of these by simply shifting a small lever, which turns a three-way valve. If the lever is pulled toward the operator, a valve closes the passage from the large diameter paddle to the indicating tube and opens the passage from the small diameter paddle, and the instrument is set for the high speed scale.

If the lever is pushed back, the opening from the small paddle is closed and the one from the large paddle opened. There is no harm done if the liquid flows over the top of the instrument as it is returned to the reservoir. In this instrument there is a reservoir on each side of the indicating tube, so that the major portion of the indicating tube is nearly over the center of gravity of the free surface of the liquid. When the car is running at low speeds, however, the column of liquid in the indicating tube is not directly over the center of gravity of the free surface, with the result that any acceleration of the car makes the liquid indicate somewhat higher than it should, while any retardation has the opposite effect, this being due to the inertia of the liquid. For automobile service these errors are not great enough to make any particular difference.

27 In the case of railroad service, the form of instrument shown in Fig. 7 will give better satisfaction. In this instrument the center of gravity of the free surface of the liquid lies at the center of the indicating tube, so that acceleration or retardation of the car, or an inclination to either side, has practically no effect on the indicator.

28 These speed indicators have ball bearings throughout and all the features enumerated above which go to make a permanently accurate instrument. An odometer giving the mileage for each trip, as well as the total mileage, is attached to each one, thus making them complete devices.

A METHOD OF OBTAINING RATIOS OF SPECIFIC HEATS OF VAPORS

By A. R. Dodge, Schenectady, N. Y.
Member of the Society

The general method of using the throttling calorimeter to determine the average value of specific heat is to supply the high pressure side with steam from which practically all moisture has been eliminated. Neglecting radiation:

$$H_1 = H_2 + C_{p_2} (T_2 \text{ sup} - T_2 \text{ sat})$$

where H is the total heat; T the temperature in degrees fahr.

2 Values determined in this way by several authorities show an increase of C_p with increasing superheat, but as has already been pointed out by others[1] the values of total heat given in the steam tables have been found too unreliable to permit of accuracy in such determinations.

3 The following method, using the throttling calorimeter for determining the ratios of the specific heats at various pressures and superheats, has not involved the use of the steam tables, and is therefore not open to errors from that source.

4 Instead of keeping the pressure and the temperature on the high pressure side of the calorimeter constant, both pressures are kept

[1] Peake: Proceedings of Royal Institute, June 28, 1905, p. 201; Denton: Stevens' Indicator, October 1905, p. 383.

To be presented at the New York Meeting (December 1908) of The American Society of Mechanical Engineers.

constant and both temperatures are allowed to vary, the steam always remaining superheated, thereby avoiding errors due to moisture when the steam is assumed to be dry and saturated in its initial condition.

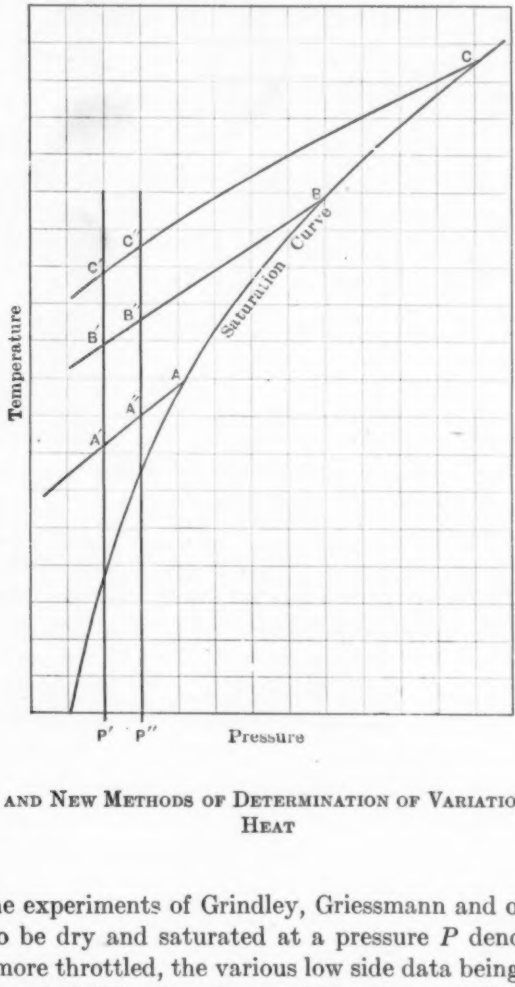

FIG. 1 OLD AND NEW METHODS OF DETERMINATION OF VARIATIONS IN SPECIFIC HEAT

5 In the experiments of Grindley, Griessmann and others, steam assumed to be dry and saturated at a pressure P denoted by A is more and more throttled, the various low side data being represented by the curve AA' (Fig. 1). A second test gives another curve BB'. Each of these is a curve of constant total heat, and the value of the total heat of either of them is that of saturated steam at the corresponding point A or B.

6 The difference between the total heats at A' and at B' can then be divided by the temperature difference $A'B'$ to give C_p.

7 The author, on the other hand, finds a number of *pairs* of points, $A'A''$, $B'B''$, $C'C''$, etc., during a run, and uses the points A' and B' instead of A and B to determine the difference in total heat between A'' and B''. In this way the use of a steam table and the assumption of dry steam are avoided, but the results of the test must be expressed in terms of the values of C_p at the standard pressure P', which was usually 15 lb. per square inch. In other words ratios are obtained, instead of absolute values.

8 The fact that it is very difficult to make sure that the steam is really dry to start with, makes this method much better than the old, even if there were no errors in the total heats given in the steam table.

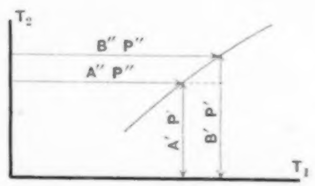

Fig. 2 Graphical Method of Locating Line, the Slope of which Indicates Variations in Specific Heat

9 The two pressures being constant through a run, the only variables are the high side temperatures ($A''P''$, $B''P''$, etc.) and the low side temperatures ($A'P'$, $B'P'$, etc.). If the first of these are plotted as abscissae and the second as ordinates, a smooth curve, Fig. 2, can be drawn which is characteristic of the two pressures. The slope of a line drawn between any two points of this curve is

$$\frac{B'P' - A'P'}{B''P'' - A''P''} \qquad [1]$$

Now from Fig. 1, between the temperatures A'' and B'', the average specific heat

$$C_{p_2} = \frac{\text{total heat}}{\text{temp.}} = \frac{H_B - H_A}{B''P'' - A''P''}$$

and between the temperatures A' and B' the average specific heat

$$C_{P_1} = \frac{\text{total heat}}{\text{temp.}} = \frac{H_B - H_A}{B'P' - A'P'}$$

As the total heats are equal

$$\frac{C_{P_2}}{C_{P_1}} = \frac{B'P' - A'P'}{B''P'' - A''P''} \qquad [2]$$

which is the same value as that found for the slope in equation 1. Therefore variations of curvature shown in Fig. 2, or variations in the tangent of the angle between a line connecting two points of the curve and the horizontal, are a measure of the variations in the specific heats between two pressures at varying superheats.

10 In this way a series of curves for different initial pressures in the calorimeter can be derived, showing the variation of C_p with relation to a standard pressure. The characteristic line K, Fig. 6, for this standard pressure must pass through the origin at 45 deg., for as there is no pressure change in the calorimeter under this condition,

$$\frac{C_{P_2}}{C_{P_1}} = \text{tangent } a = 1$$

DESCRIPTION OF APPARATUS

11 The general arrangement of boilers, calorimeter, etc., used in these tests is shown in Fig. 3 and 4. This calorimeter was designed after two years of experimental work, during which improvements were made to eliminate radiation, conduction, thermometer errors, temperature lag, and errors in temperature due to velocity of the steam jet. The water was forced by a high pressure pump into two flash boilers connected in series by means of which the superheat could be raised to any desired amount.

12 The steam was then passed to the separator drum S at which the temperature was controlled by injecting water. The pressure and temperature entering the high pressure side B of the calorimeter were held constant with practically no variation.

13 The low pressure side of the calorimeter was jacketed, and the steam in the jacket was held at nearly the same temperature as the exhaust from the calorimeter by means of a superheated steam supply

at atmospheric pressure. The steam passing through the calorimeter was weighed after being condensed, and Fig. 4 shows the relation between the absolute pressure on the high side and the steam flow.

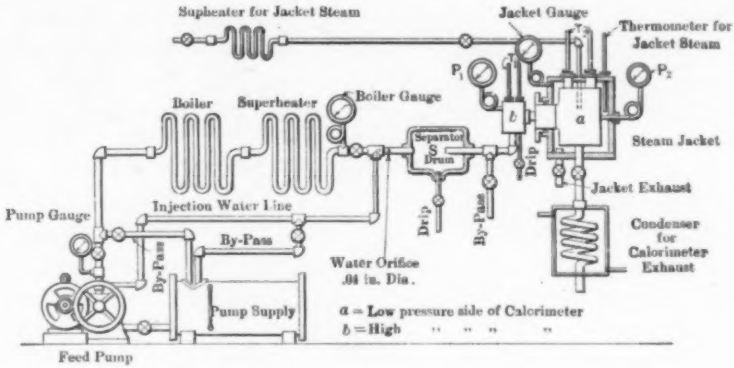

FIG. 3 ARRANGEMENT OF APPARATUS

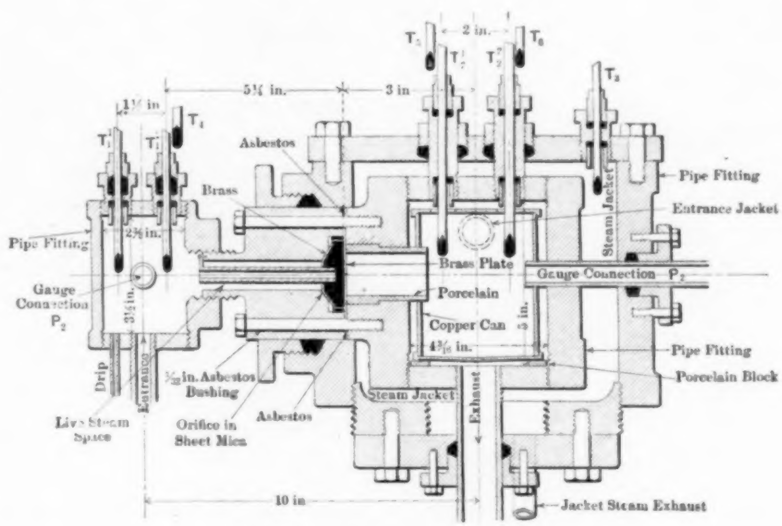

FIG. 4 THROTTLING CALORIMETER

14 Orifices of two sizes were used, the diameters of which were 0.052 in. and 0.1 in. The object of using the larger orifice was to eliminate the effect of possible radiation, although in addition to jacketing the low pressure chamber, the jacket was thoroughly lagged with

magnesia. No different results were obtained, however, when using the larger orifice, indicating that radiation was negligible. The question of radiation was further investigated by measuring the drop in superheat in the steam from one chamber of the calorimeter to the other with the same steam flows as during the regular tests but with no drop in pressure as the orifice was entirely removed from the calorimeter. These tests indicate that there is a slight correction in spite of all precautions, but of such small limits that the ratios of the specific heats is not affected.

15 Each of the varying pressure tests, of which there are 85, were run from six to eight hours, each initial temperature point being held constant for about one hour. All pressures on the high pressure side were held constant by means of spring gages calibrated before and after each test, using a reliable dead weight tester.

16 The pressure on the exhaust side of the calorimeter was held at 15 lb. abs. by means of a U-tube gage filled with mercury. The piping connecting this U-tube to the low pressure chamber was closed at the end and holes were drilled through the pipe to avoid a possible error from the velocity head of the steam jet through the orifice. Tests were also made with 165, 8.12 and 2.97 lb. abs. on the low pressure side.

17 The temperature was held constant by means of a calibrated thermometer on the high pressure side. The stem of this thermometer was packed where it passed through the calorimeter wall, and the bulb placed in direct contact with the steam. Another calibrated thermometer was also used in the high pressure chamber as a check. Stem corrections were applied in accordance with the following formula, which has been fully verified for such conditions:

$$\text{Correction} = (T_1 - T_2)(T_1 - T_3)\ 0.000087 \text{ deg. fahr.}$$

where

T_1 = observed reading of the chamber.
T_2 = reading just visible above chamber casing.
T_3 = temperature cf exposed stem.

18 The thermometers were frequently calibrated in wet steam supplied to a drum at pressures up to 600 lb. These pressures were determined and held at the correct value by a dead weight testing apparatus. The correct temperature at these pressures was determined by thermometers calibrated by the Bureau of Standards at Washington. The thermometers were also corrected for pressure on the bulb by the subtraction of 1 deg. fahr. for each 100 lb. gage

pressure, a correction determined by separate experiments in connection with these tests.

19 The thermometers on the low pressure side were also placed directly in the steam and properly packed to prevent leakage around the stem.

METHOD OF MAKING TESTS

20 Readings were not recorded until the apparatus was thoroughly heated and conditions constant.

21 In order to prevent temperature lag, the initial conditions were held constant for an hour if necessary and frequent readings taken on the lower temperature T_2. The initial temperature could be con-

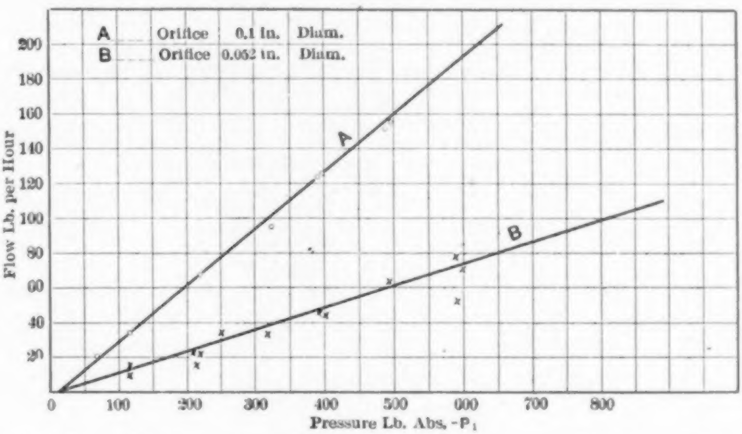

Fig. 5 Steam Flow through Calorimeter at Different Pressures under Average Superheated Conditions

trolled within one-half a degree of the desired value. There was no variation in the initial and final pressures which were both controlled by throttling. After all conditions had remained constant over a satisfactory period the superheat on T_1 was changed and the operation was repeated, the pressure conditions remaining unchanged.

22 The maximum velocity of the steam in the separator drum after the water was injected was never greater than $\frac{25}{100}$ ft. per second; therefore, approximately four seconds elapsed while the steam was passing through the drum, giving the highly superheated mixture sufficient time to become of uniform temperature. The small quantity of water injected, together with the fact that there were three drip pipes between the water orifice and the thermometer on the high

pressure side, as well as the location of the thermometer bulbs opposite the jacketed orifice, all indicate that the temperature of the sample admitted to the orifice was correctly observed.

23 In order to investigate the effect of the kinetic energy of the steam jet in the low pressure side, four screens of fine copper gauze

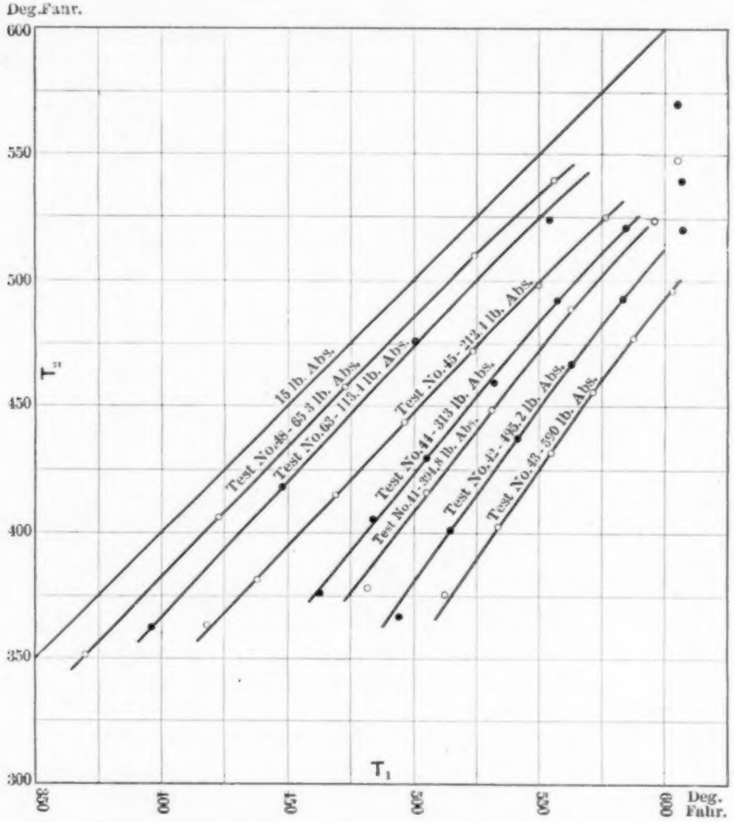

FIG. 6 DIAGRAM SHOWING RELATION BETWEEN TEMPERATURES IN HIGH AND LOW PRESSURE CHAMBERS. THE TANGENTS OF THESE LINES INDICATE THE LAW OF VARIATION OF SPECIFIC HEAT WITH PRESSURE AND TEMPERATURE.

were placed in series in the path of the jet between the orifice and the low pressure thermometers but the same results were obtained without the screens by raising the thermometers out of the path of the jet.

24 The results of 35 runs made with the apparatus in its final form are shown in the subjoined tables. A few characteristic tests

TABLE 1 RESULTS OF 35 RUNS

Test No.	P_1	P_2	T_1sat	T_1	T_2	Jacket T_3	Steam Flow Per Hour	Dia. Orifice In.	Points	Slope $\frac{Cp_1}{Cp_2}$
35	592.9	165.4	485.5	598.1	514.5	505.	82.0	.052		
36	604.8	164.8	487.9	603.7	519.7	507.	78.0	.052		
				580.8	494.5	487.	84.0		1–3	1.190
				560.5	468.3	455.	88.0		2–4	1.259
				538.9	441.8	445.	92.0		3–5	1.297
				512.8	406.4	415.	96.0			
37	511.0	165.0	469.7	604.3	534.0	520.	56.0	.052		
				578.3	507.0	510.	55.0		1–3	1.098
				551.9	476.5	480.	52.0		2–4	1.196
				519.8	437.0	435.	56.0		3–5	1.213
				498.3	411.5	415.	63.0			
38	316.9	164.4	423.5	608.8	555.0	545.	27.0	.052		
				591.0	542.3	530.	27.5		1–3	0.921
				538.0	489.8	490.	29.0		2–4	1.017
				505.8	455.7	460.	29.7		3–5	1.027
				473.0	423.1	430.	30.5			
39	396.0	164.5	444.8	607.2	548.0	535.	38.0	.052		
				569.8	514.5	515.	37.2		1–3	1.050
				505.8	441.4	445.	38.4		2–4	1.150
				473.8	404.2	405.	41.0			
40	398.2	15.0	444.7	605.8	524.0	515.	43.0	.052		
				558.1	477.0	510.	43.5		1–2	0.985
				483.7	387.5	382.	46.0		2–3	1.202
41	394.8	15.0	443.2	596.2	524.2	510.	44.5	.052		
				563.0	488.0	480.	45.0		1–3	1.167
				531.2	448.3	445.	46.0		2–4	1.249
				505.2	415.8	415.	48.5		3–5	1.400
				481.3	378.5	380.	49.5			
42	495.2	15.0	466.2	606.6	519.5	515.	56.0	.052		
				584.1	492.8	490.	57.0		1–3	1.225
				562.5	465.5	450.	57.5		2–4	1.301
				541.3	437.1	430.	57.7		3–5	1.373
				515.2	400.5	400.	62.0		4–6	1.500
				494.2	366.5	370.	64.0			
43	590.0	15.0	485.8	603.3	495.5	485.	75.0	.052		
				587.8	476.5	473.	77.5		1–3	1.312
				572.4	454.9	445.	79.0		2–4	1.382
				555.5	431.8	430.	80.0		3–5	1.376
				533.9	401.9	415.	83.0		4–6	1.331
				512.8	374.9	385.	85.0			
44	313.0	15.0	422.0	606.7	540.0	525.	32.5	.052		
				585.0	520.0	510.	33.0		1–3	1.020
				558.7	491.0	485.	33.5		2–4	1.174
				531.8	457.5	450.	34.0		3–5	1.163
				505.6	429.2	420.	34.5		4–6	1.109
				484.3	404.9	415.	35.5		5–7	0.988
				462.1	376.3	365.	36.0			

TABLE 1 RESULTS OF 35 RUNS—Continued

Test No.	P_1	P_2	T_1sat	T_1	T_2	Jacket T_3	Steam Flow Per Hour	Diameter Orifice	Points	Slope $\frac{Cp_1}{Cp_2}$
45	212.4	15.	388.0	604.5	548.0	525.	19.0	.052		
				576.5	525.0	505.	21.2		1–3	0.927
				549.5	497.1	490.	21.6		2–4	1.006
				522.8	471.0	455.	22.0		3–5	1.020
				496.0	442.5	445.	22.2		4–6	1.028
				469.3	415.0	415.	22.5		5–7	1.063
				438.3	381.1	375.	23.0		6–8	1.022
				418.0	362.6	355.	23.5			
46	112.4	15.	336.0	450.2	409.0	405.	10.0	.052		
				385.9	352.3	345.	10.0			
47	112.2	15.	336.0	601.0	572.3	535.	34.0	.100		
				570.0	549.0	565.	32.0		1–3	0.948
				529.0	504.0	490.	34.0		2–4	1.025
				498.3	475.5	475.	35.0		3–5	1.016
				468.0	442.0	440.	36.5		4–6	1.072
				411.0	381.9	375.	37.5		5–7	1.063
				374.5	342.5	330.	38.5			
48	65.3	15.	298.5	555.5	539.1	535.	20.0	.100		
				524.0	510.1	500.	20.5		1–3	0.960
				473.0	457.4	450.	22.0		2–4	1.019
				421.6	405.8	400.	22.0		3–5	1.033
				370.5	351.4	355.	23.0			
49	216.6	15.		Not worked up				.052		
50	214.7	15.	387.8	602.7	546.7	535.	15.0	.052		
				560.2	510.5	510.	16.5		1–3	0.972
				517.9	464.3	455.	17.0		2–4	1.150
				470.8	407.7	405.	17.5		3–5	1.202
				429.6	358.2	355.	19.0			
51	595.0	15.	486.2	595.0	465.0	465.	51.0	.052		
52	595.3	15.	486.7	599.3	493.3	487.	52.0	.052		
				580.3	468.0	452.	53.0		1–3	1.319
				567.4	451.2	440.	53.0		2–4	1.730
				541.3	400.5	390.	55.0		3–5	1.853
				509.5	343.9	340.	55.0			
53	594.9	15.	487.0	599.0	490.9	490.	45.0	.052	1–2	1.450
				560.8	435.6	425.	47.0		2–3	1.803
				520.1	362.2	360.	50.0		1–3	1.630
54	215.7	15.	388.0	600.0	562.2	550.	65.0	.100		
				501.0	456.0	450.	70.0		1–3	1.110
				459.0	405.5	400.	70.0		2–4	1.208
				417.0	354.6	345.	75.0			
55	215.7	15.	388.5	600.0	562.2	550.	62.0	.100		
				521.0	477.5	470.	63.0		1–2	1.071
				437.5	381.3	375.	67.0		2–3	1.152

TABLE 1 RESULTS 35 RUNS—Continued

Test No.	P_1	P_2	T_1sat	T_1	T_2	Jacket T_3	Steam Flow Per Hour	Diam. Orifice in	Points	Slope $\frac{Cp_1}{Cp_2}$
56	495.7	15.5	466.6	555.6	469.0	460.	151.0	.10		
				524.6	425.0	420.	153.5		1–2	1.451
				492.2	373.5	355.	160.0		2–3	1.280
57	215.8	15.0	387.7	605.8	562.7	555.	60.0	.10		
				579.2	536.8	516.	65.0		1–3	0.973
				552.0	510.4	500.	67.5		2–4	1.073
				526.8	480.6	475.	67.5		3–5	1.222
				499.2	445.9	444.	71.0		4–6	1.135
				462.8	408.0	405.	70.0		5–7	1.122
				426.6	364.4	365.	71.0			
58	215.8	15.0	387.1	589.5	546.5	530.	63.0	.10		
				536.0	490.9	483.	65.0		1–3	1.082
				483.7	432.0	425.	68.0		2–4	1.134
				441.3	383.5	380.	69.0			
59	489.8	15.0	465.7	601.6	517.0	500.	150.0	.10		
				575.2	484.6	480.	150.0		1–3	1.284
				538.2	435.5	432.	155.0		2–4	1.388
				518.2	405.5	400.	157.0		3–5	1.521
				501.7	380.0	379.	157.0		4–6	1.592
				480.5	345.5	345.	160.0			
60	392.0	15.0	442.8	540.4	457.5	435.	120.0	.10		
				514.0	425.2	375.	120.0		1–3	1.382
				482.6	377.7	310.	125.0		2–4	1.541
				461.6	344.4	320.	125.0			
61	322.0	15.0	424.4	602.9	545.0	494.	95.0	.10		
				576.8	518.2	485.	95.0		1–3	1.204
				557.0	489.7	475.	96.0		2–4	1.166
				525.5	458.4	430.	97.5		3–5	1.059
				498.9	428.2	420.	98.0		4–6	1.294
				472.7	390.0	365.	98.0		5–7	1.476
				446.6	351.0	349.	5100.0			
62	386.0	15.0	441.8	601.8	533.5	515.	117.0	.10		
				549.6	474.4	455.	135.5		1–2	1.132
				471.9	364.9	360.	140.0		2–3	1.409
63	113.4	15.0	337.4	605.4	569.8	555.	34.0	.10		
				554.0	523.1	514.	35.0		1–3	0.910
				501.1	474.9	460.	35.0		2–4	0.990
				447.8	418.0	390.	35.0		3–5	1.071
				395.5	361.8	355.	35.0			
64	589.7	15.0	488.0	602.9	492.1	481.	52.5	4 openings each .0139		
				581.7	465.0	452.	55.0		1–3	1.372
				555.1	426.4	421.	57.5		2–4	1.400
				533.5	397.4	391.	60.0		3–5	1.168
				502.0	364.4	356.	60.0			

TABLE 1 RESULTS OF 35 RUNS—Continued

Test No.	P_1	P_2	T_1sat	T_1	T_2	Jacket T_3	Steam Flow Per Hour	Diam. Orifice In.	Points	Slope Cp_1 Cp_2
65b	313.3	2.97	421.3	560.3	518.8	500.0	27.5	4 openings each .0139		
				533.3	462.3	448.0	27.5	-	1–3	1.058
				491.5	414.2	407.0	30.0		2–4	1.197
				460.5	375.1	369.0	30.0			
66	315.8	15.00	423.0	612.8	544.5	527.0	20.0	.0139		
				581.6	514.7	501.0	23.0		1–3	1.001
				548.8	480.4	461.0	24.0		2–4	1.096
				516.5	443.3	432.0	25.0		3–5	1.269
				484.6	405.3	398.0	25.0		4–6	1.171
				452.4	368.3	365.0	27.0			
67	315.8	15.00	423.7	621.0	549.4	528.0	22.5	.0139		
				587.3	517.4	493.0	23.0		1–3	1.021
				553.8	480.7	450.0	25.0		2–4	1.029
				521.0	442.5	434.0	25.5		3–5	1.146
				488.5	405.9	393.0	26.0		4–6	1.160
				455.5	366.5	360.0	26.0			
68	316.4	15.00	422.0	618.5	563.7	550.0	97.5	.10		
				583.5	527.0	507.0	99.0		1–3	1.104
				551.0	489.1	461.0	100.5		2–4	1.177
				518.5	450.5	440.0	103.0		3–5	1.219
				486.1	410.0	394.0	102.5		4–6	1.355
				453.3	362.1	352.0	105.0			
69	315.8	8.12	421.5	614.5	558.2	541.0	90.0	.10		
				581.5	523.0	510.0	92.0		1–3	1.120
				549.5	485.3	469.5	95.5		2–4	1.170
				517.0	447.5	441.0	99.0		3–5	1.214
				484.5	406.3	395.0	101.5		4–6	1.372
				452.0	358.2	355.0	105.0			

have been plotted in curve form, in Fig. 6. The deviation from a straight line is slight, but even this amount would account for a considerable variation in C_p due to the temperature change.

25 The curvature of these lines thus shown graphically is brought out arithmetically in the tables, column 11. To avoid magnified errors in the derivative, the slope is taken between points not adjacent, the first with the third, the second with the fourth, etc.

26 Each test is considered by itself rather than drawing one curve through points from a series of tests made under the same initial and final pressures.

27 The discrepancy of two or more tests under this latter method

is sufficient to obscure the tendency to slight curvature shown by the individual tests.

28 The first column gives the test number, the second and fifth the high side conditions, the third and sixth the low side conditions, the fourth the observed saturated temperature with initially wet steam, the seventh the jacket temperature, the eighth the steam flow per hour, the ninth the diameter of the steam orifice, and the last column the slope or ratio of C_p under the high side condition to C_p under the low side condition. Values of specific heat cannot be deduced from these tables without definite initial values; with the proper initial values a method is available for obtaining complete curves of specific heat for all conditions.

AN AVERAGING INSTRUMENT FOR POLAR DIAGRAMS

By W. F. Durand, Stanford University, Cal.

Member of the Society

Some years ago the present author called attention in a published note[1] to a form of integrating or averaging instrument for diagrams plotted in polar coördinate, to which, as is well known, the ordinary planimeter is not applicable. The application of the instrument was at that time considered only for diagrams plotted on straight radial lines, such as diagrams of crank turning effort, etc. Since that time the use of dial-recording gage instruments which trace a diagram in polar coördinates but with a curvilinear path of the tracing arm has become greatly extended, and such gages are now in common use for recording various engineering quantities, mechanical, thermal and electrical.

2 Recent discussion in the engineering press[2] has indicated a renewed interest in the question of averaging instruments for such diagrams or charts, and this fact has led to a restudy of the instrument previously described with reference to its use for all forms of diagrams of this character. Believing that the description and use of such an instrument may be of interest to the members of the Society, the present brief paper has been prepared.

[1] Sibley Journal of Engineering, November, 1893.

[2] Power, March 3, April 27, 1908.

To be presented at the New York Meeting (December 1908) of The American Society of Mechanical Engineers.

GENERAL DESCRIPTION AND MODE OF USE

3 It is obviously necessary in applying an instrument to such diagrams to presuppose a uniform radial scale. This is exactly analogous to the assumption of a uniform scale for the vertical ordinate in the indicator card when averaging by the ordinary planimeter. This implies simply that equal increments in the radial distance of the tracing point from the center correspond to equal increments of pressure, or voltage, or temperature, or whatever quantity may be under measurement. The problem is then for any angle of the disk corresponding to any given period of time, to find the mean radius, and thus the mean pressure, temperature or voltage.

4 This cannot be done with the ordinary planimeter, since, as is well known, the area of the diagram in polar coördinates is proportional to the square of the radius and to the angle. By the use of the ordinary planimeter, therefore, the mean square of the radial ordinate can be found, and then the square root of this can be taken. This is not the same as the mean radius, however, a point easily proven by numerical example.

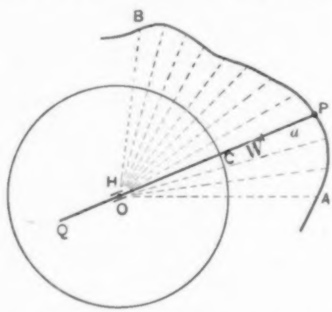

FIG. 1 DIAGRAM WITH RADIAL MOVEMENT OF TRACING POINT

5 Consider now the arrangement in Fig. 1. Let AB denote a curve which for the present we may consider as traced by a point moving in and out on a straight radial line instead of on a curved arc as in most forms of such recording gages. Let O be the center, and at O let H denote a socket pivoted at O and permitting the rod PQ to slide freely back and forth as required to permit the tracing point P to follow the curve AB. Also let W be a wheel carried on PQ as an axis and graduated in the same general manner as the integrating wheel of a planimeter. Then it will be plain that the wheel W can respond to movement in angle only, and that movement of the rod

PQ radially, or in the direction of its own length, will produce no movement and no reading of the wheel *W*. It is also seen that the movement of the wheel will be proportional to the radius *WO* and that this differs from *PO* by a constant distance $PW = a$. It results that the final movement of the wheel *W* will be proportional to the angle moved through by the arm *PQ*, and to the radius *OW* varying from point to point along the curve. As shown in the appendix the reading for any part of the curve, as *AB*, is actually proportional to the product of the angle *AOB* and the mean radius for the curve between these points. If then we divide this reading by the angle *AOB* expressed in circular measure we shall have a quotient proportional to the mean radius *OW*. If then we add to this the constant distance *WP* we shall have the true mean value of the radial ordinate *OP*. If the curve is plotted or drawn with reference to a base circle of

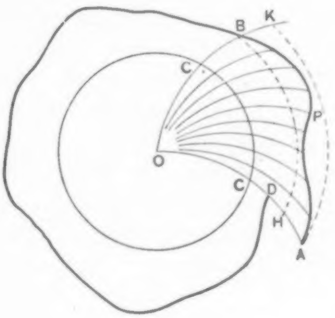

FIG. 2 DIAGRAM WITH TRACING POINT MOVING IN ARC OF CIRCLE

radius *OC* as datum, then the radius *OC* being subtracted, the remainder will be the true mean value of the ordinate *CP*. If *WP* is made equal to *OC*, as may readily be done by a suitable adjustment in the instrument, then the two corrections will balance and the mean value of the radial ordinate *CP* will be given directly as the quotient of the reading of the wheel divided by the angle *AOB* expressed in circular measure. If the chart corresponds to 24 hours for a complete circumference, then the angular measure to be used as divisor will be 0.2618 per hour.

6 In the usual form of instrument the marking point, instead of moving on a straight radial line as assumed in Fig. 1, moves on the arc of a circle as in Fig. 2. Then in the appendix it is shown that an instrument exactly the same as above described may be used by observing the following general instructions:

7 In using the instrument for diagrams plotted or traced as in Fig. 2 the tracing point of the instrument must start and finish at the same distance from the center of the circle. If then the diagram covers a complete revolution, as in Fig. 2, with beginning at A and end at D, it is only necessary to trace from D along the curved arc ODA to A thus making the start and final finish both at A. If the diagram covers only part of a complete revolution, as for example APB, then beginning at A the tracing point is carried along APB, and then from B along the curved path BK to a point K, at the same distance from the center as A. Or otherwise beginning at B the tracing point is carried along BPA, and then along AH to a point H at the same distance from O as B.

8 In either case, the reading being taken, the mean radial ordinate is found from it by the same treatment as described above for the straight line radial path.

9 It is thus seen that the integrating or averaging instrument suited to the treatment of such diagrams is of the simplest possible form, consisting of a plain straight arm QP, Fig. 1, which serves as axis for the wheel W and slides freely through a socket H pivoted at the center of the diagram O; and that by the use of such an instrument diagrams of this character may be mechanically averaged, no matter what the actual character of the path followed by the tracing point of the recording gage, and no matter what fraction of a complete revolution the diagram may cover.

APPENDIX

10 The quantity to be determined in such diagrams is the time mean of the quantity measured by the radial ordinate. But since angular motion is made proportional to time, we may represent the desired mean by the following integral formula:

$$r = \frac{\int r d\theta}{\int d\theta} = \frac{\int r d\theta}{\theta}$$

11 Now, in Fig. 3, let $ABCD$ denote a curve drawn by a tracing point which moves on the arc of a curve shown by OAK. Then let OK, OL, OM, etc., denote a series of consecutive positions of the curve OAK, at differential angular intervals $d\theta$. Then for the actual curved path $ABCD$ substitute the broken line path made up of a series of arcs each $r d\theta$ in length, and the series of differential bits of

the curve OAK as shown. Then at the limit the record of any integrating or averaging instrument will be the same, whether the tracing point is carried along the curve or along the broken line substitute as shown.

12 Then suppose an integrating instrument, as shown in Fig. 1, applied to such a diagram, and let the tracing point P be carried along the zig-zag path. The record of the wheel will be made up of two parts:

a That due to the circular arcs $rd\theta$ and representing by summation the value of $\int rd\theta$.

b That due to the differential portions of the arc OAK.

13 Now it is clear that if the diagram extends all the way around from A through BCD to A again the differential elements of the curve OAK may be considered as existing in pairs, and that for every

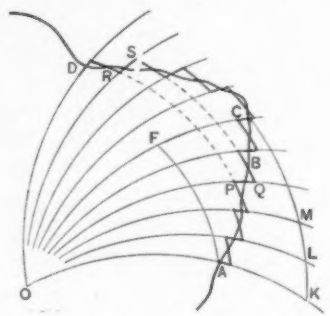

Fig. 3 Curve Traced by Pointer Moving in Arc of Circle

element traversed in the *outward* direction, there will be an equal element traversed in the *inward* direction. PQ and RS donote the members of such a pair. The record for such a pair will therefore disappear in the summation, and hence for all the pairs, and hence for the diagram as a whole. In such case therefore part *b* above becomes O and the record of the wheel for the entire diagram consists simply of *a* or of $\int rd\theta$.

14 This reasoning is seen to be entirely general and independent of the character of the path OAK, and hence true whether it be the arc of a circle, a straight line or any other path.

15 In case the curve occupies only part of the revolution, as ABC, then it is clear that in going from A to C the record as above will involve the two parts, *a* and *b*, and that the latter will remain

included in the final result and will represent the summation of record due to the elements of *OAK* between *A* and *C*. It is clear that this will be the value of $\int r d\theta$ for an arc *FC* and hence that it will be cancelled by carrying the tracing point of the instrument back from *C* to *F*.

16 This reasoning is independent of the extent of the arc and hence equally true for an entire revolution or arc of 360 deg. where the diagram does not finish at the same radial distance as at the start, see Fig. 2. Hence in such a case it is necessary only to trace along *ODA* from *D* to *A*, to cancel element *b* above and thus to find the value of $\int r d\theta$ for the entire 360 deg.

17 It follows therefore that in all cases the correction for element (*b*) of the record is made by tracing from the terminal point of the curve along the path representing zero time change, to a point lying in a circumference passing through the initial point. Or in other words, in order to eliminate element *b* of the record, the tracing point must start and finish at the same distance from the center; and if the diagram does not naturally fulfil this condition then the necessary portion of the no-time-change path must be used to supplement the diagram itself.

18 It is clear that this reasoning is independent of the character of the curve *OAK*. It may be noted however as obvious, that if the path *OAK* becomes a straight line the value of the correction becomes *O*, and the reading of the instrument is hence independent of element *b*, no matter whether the diagram begins and ends at the same radial distance from the center or not.

THE SLIPPING POINT OF ROLLED BOILER TUBE JOINTS

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Non-Member

The object of this paper is to supply data regarding the behavior of joints made by the familiar process of rolling boiler tubes into containing holes. Articles dealing with this subject give but little information except as to the ultimate holding power of such joints, and since the joint may be condemned on account of leakage rather than for lack of maximum holding power it seems desirable to have information as to the behavior of the joint through its full range of resistance.

2 When a tube has started from its original seat the fit may be no longer continuous at all points and a leak may result although the ultimate holding power of the tube may not be impaired. A small movement of the tube under stress is then the preliminary to a possible leak and it becomes of interest to know at what stress this slipping begins. A knowledge of the slipping point of a tube in its relation to the ultimate holding power is somewhat analogous to a knowledge of the elastic limit of materials in relation to their ultimate strength, in that working stresses should be kept within the smaller values.

3 The analogy is further warranted by the appearance of the load-slip diagram from such a joint, which has a general resemblance to stress-deformation diagrams of tension tests of steel.

To be presented at the New York Meeting (December 1908) of The American Society of Mechanical Engineers.

The professional papers contained in The Journal are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present. They are issued to the members in confidence, and with the understanding that they are not to be published even in abstract, until after they have been presented at a meeting. All papers are subject to revision.

4 Fig. 1 is a typical diagram of the action of a 3-in. twelve-gage, Shelby cold drawn tube expanded into a straight machined hole in a 1-in. plate, the tube end projecting $\frac{1}{2}$ in. and not flared. The figures to the left give the total force applied to pull the tube from its

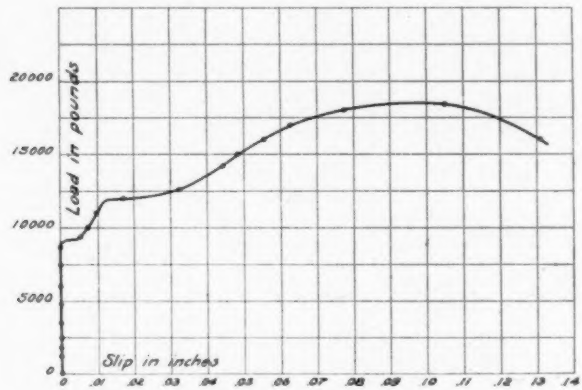


FIG. 1 TYPICAL LOAD-SLIP DIAGRAM

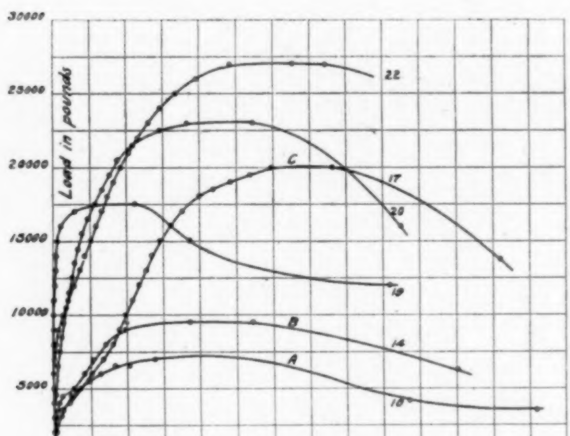


FIG. 2 LOAD-SLIP DIAGRAMS FROM 3-IN. TUBES ROLLED INTO $\frac{1}{2}$-IN. PLATES

seat; the figures below the total slip or movement of the tube through the hole. The curve shows the relation between the load applied and the corresponding slip.

5 The tube in this joint began to move at 9000 lb. and shows a decided slip at 12 000 lb. reaching an ultimate holding strength of 18 000 lb.

6 There is a considerable probability that this joint would leak after the tube had slipped and be condemned because of its leakiness.

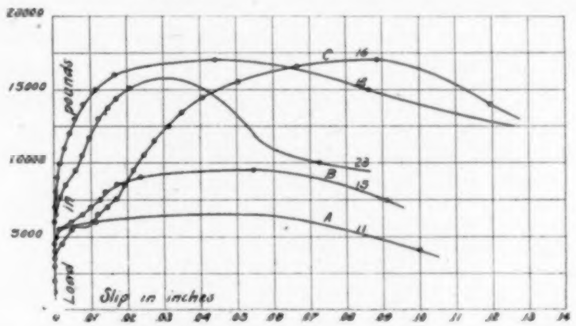


FIG. 3 LOAD-SLIP DIAGRAMS FROM 3-IN. TUBES ROLLED INTO ⅜-IN. PLATE

This slip occurs at 50 per cent of the ultimate holding strength of the joint and at 29 per cent of the elastic limit of the material in the tube.

7 There is then a considerable field for improvement in which to raise the slipping point to a higher per cent of the ultimate strength of the joint or of the elastic limit of the tube. The usual design

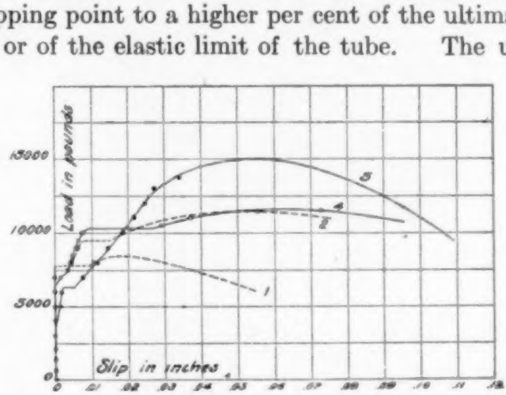


FIG. 4 COMPARISON OF LOAD-SLIP DIAGRAMS WITH STRAIGHT AND FLARED TUBE ENDS

seems sufficient for most cases, but where high pressures are used or where the stresses due to temperature variations are large, a joint with a higher initial slipping point seems necessary.

8 In many boiler designs a certain few of the tubes seem to be more highly stressed in service than others and for such designs a joint of

high initial slip would be an advantage. As an illustration, a 3-in. tube under 225 lb. boiler pressure would be urged from its seat by a force of about 1600 lb. due to pressure alone. In many tests the initial slip comes at about 6000 lb. This gives a factor of safety of 3.75 within the slipping point to take care of the unknown temperature stresses. If the design calls on the tube to act as a stay and support the pressure of but 16 sq. in. this factor of safety within the slipping point is reduced to about 1.7.

9 In attempting to strengthen the usual joint it might appear that harder rolling of the tube would raise this slipping point, but

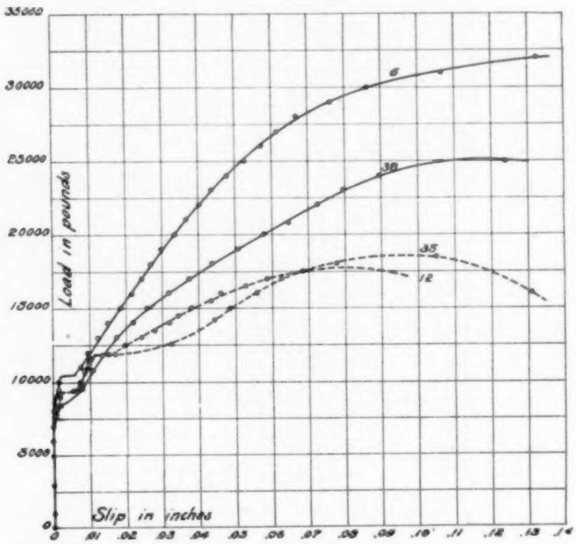


FIG. 5 COMPARISON OF LOAD-SLIP DIAGRAMS WITH TUBES IN STRAIGHT AND IN TAPERED HOLES

experiment does not show this. Harder rolling within certain limits will raise the ultimate holding power but has little effect on the initial slip. This is shown in Fig. 2 and 3, where tubes were rolled into straight machined holes in $\frac{1}{2}$ in. and $\frac{5}{8}$ in. plates. In these the tubes A,B,C were rolled respectively light, medium and heavy. Tubes A were rolled until the sheet showed a band of loosened mill scale about the hole $\frac{1}{16}$-in. wide, tubes B $\frac{1}{8}$ in. wide, and tubes C $\frac{1}{4}$-in. wide. The general agreement of the slipping points for the several degrees of rolling is noticeable although the ultimate holding power has been elevated by the harder rolling.

10 The recommendation to flare the projecting end of the tube has high authority and is of value, but while this raises the ultimate holding power it does not alter the original slipping point. It seems evident that this flared portion would have to be moved into the hole before its metal could come into play and this initial movement might be the cause of leakage. In Fig. 4 a comparison is made between tubes with straight and flared ends.

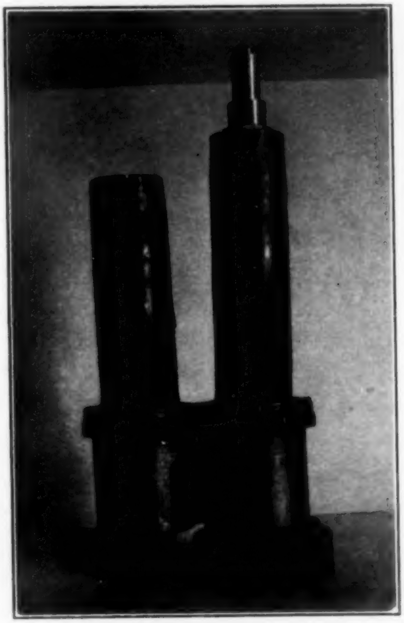


FIG. 6 TUBES EXPANDED INTO MALLEABLE IRON BOXES AND SUBJECTED TO HYDRAULIC PRESSURE

11 The ends of tubes 1 and 2 were not flared, while the ends of tubes 4 and 5 were well flared and in number 5 the hole was also slightly chamfered. Evidently the point of initial slip has not been greatly influenced by the flaring of the ends, though it is probable that a tube drawn into a hole would be less likely to leak if flared. To discover a more rigid type several forms of tube openings were tested.

12 If the holes into which the tubes are rolled are tapered $\frac{1}{16}$ in. in diameter per inch in thickness of the plate the first slipping point is hardly affected, but the joint is more rigid after a slip of 1/100 in. and the ultimate strength is increased. In Fig. 5 curves 12 and 35

represent the results from straight holes; while curves 6 and 38 are typical of those having tapered holes. These curves show the slipping points as agreeing in general, but those from tapered holes rise more rapidly and are thus more rigid.

13 During the progress of these experiments a form seemed wanted, to put the rolled metal under an initial stress in the direction of the axis of the tube, thus reinforcing the frictional resistance and making movement unnecessary to develop a larger resistance to the first slip. A tapered hole in the sheet was therefore given a reverse taper also, so that its smallest diameter was $\frac{1}{8}$ in. from the tube side of the sheet.

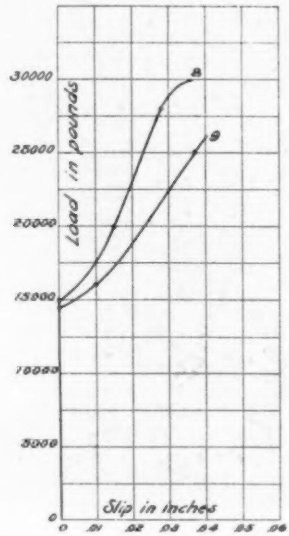


FIG. 7 LOAD-SLIP DIAGRAMS FROM 3-IN. TUBES ROLLED INTO MALLEABLE IRON BOXES AND SUBJECTED TO HYDRAULIC PRESSURE

14 This amounted to a slight chamfering of the inner side of the tube sheet. Rolling the tube against the two tapers would develop such stresses along the tube as should help to resist movement. In Fig. 11 numbers 36, 44, 26, 25, 38 and 37 had double taper. Compared with the straight holes the general effect was to lower the slipping point somewhat but increase the rigidity. Two such tubes were tested by fluid pressure, the tubes having one inch bearing in malleable boxes of the form used in the Parker boiler. The combination of tubes, with closed ends, and the box were filled with oil and an

Form of Joint	Taper per inch	Test No.	Load in pounds at point of: Initial Slip	Load in pounds at point of: Slip = $\frac{1}{100}$ inch	Load in pounds at point of: Ultimate Load	Slip in inches at point of Ult. Load
Tube Sheet 1" thick						
Straight and Tapered		1	7800	8000	8400	.02
		2	7800	9500	11400	.05
	.06	7			17200	.12
Flared, Straight, and Tapered	.06	4	6000	10300	11500	.07
Flared, Chamfered, Straight, and Tapered	.06	5	4000	7600	15000	.06
Tapered and Straight	.06	3	7000	7800	26000	.112
Double Taper	.10	8	15000	17500	30000	.04
		9	14500	15500	21000	
Tube Sheet $\frac{5}{8}$" thick						
Straight		11	5000	6100	6400	.03
		15	4500	7000	9500	.04
		16	3700	5900	17000	.088
Punched		18	8000	14700	17800	.044
Double Taper	.10	23	6500	12000	16000	.04
Tube Sheet $\frac{1}{2}$" thick						
Straight		10	2000	5600	7400	.03
		14	2000	6800	9500	.035
		17	3000	6000	20000	.06
Punched		19	10000	17200	17500	.022
		20	3500	17000	23000	.036
Double Taper	.10	22	7000	15000	27000	.048
Tube Sheet $\frac{3}{8}$" thick						
Straight		13	1300	7000	18000	.045
Punched		21	8000	15200	16500	.027

Fig. 8 Results from Tests of 3-in. 12-Gage Cold-Drawn Boiler Tubes Rolled into Various Forms of Tube Openings

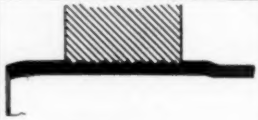
Form of Joint	Serrations: Number per inch	Serrations: Depth in inches	Test No.	Load in pounds at point of: Initial Slip	Load in pounds at point of: Slip = 1/64 inch	Load in pounds at point of: Ultimate Load	Slip in inches at point of Ult. Load
Tube Sheet 1" thick							
			12	7000	11500	17700	.085
			24	6000	7000	20000	.12
			27	9000	9500	21000	.10
			32	6400	6000	6400	–
Straight Machined Hole			34	6800	10500	11800	.035
			35	8800	11200	18400	.105
Average				7333	9283	15833	.089
			25	3500	14000	23000	.08
			26	5500	12800	19700	.047
Taper 1/16" in diam. per inch			36	8200	12600	16500	.042
			37	7500	8900	23000	.178
Double Taper			38	7000	10300	25000	.124
			44	7500	14400	33000	.069
			6	8500	12200	32000	.133
Single Taper			39	13500	17500	22600	.354
Average				7650	12837	24850	.128
	10	.005	45	10000	15500	15800	.015
	10	.010	46	22000	27500	27500	.008
	10	.015	47	45000	50000	50000	.012
Serrated	10	.020	48	43000	45000	45000	.003
	10	.015	33	23000	37500	37700	.012
	10	.015	40	25000	35000	35000	.01
	10	.007	41	16500	23800	24200	.015
	16	.007	43	21000	27200	27200	.006
Serrated	64	.002	42	15000	16000	16000	.010

FIG. 9 RESULTS FROM TESTS OF 3-IN. 12-GAGE COLD-DRAWN BOILER TUBES ROLLED INTO VARIOUS FORMS OF TUBE OPENINGS

accurately ground plunger forced in under the testing machine, as shown in Fig. 6. The results are shown in Fig. 7 as No. 9.

15 No. 8 was a tube in a similar box forced out by direct loading in the machine. The minute movement of the tubes in both tests

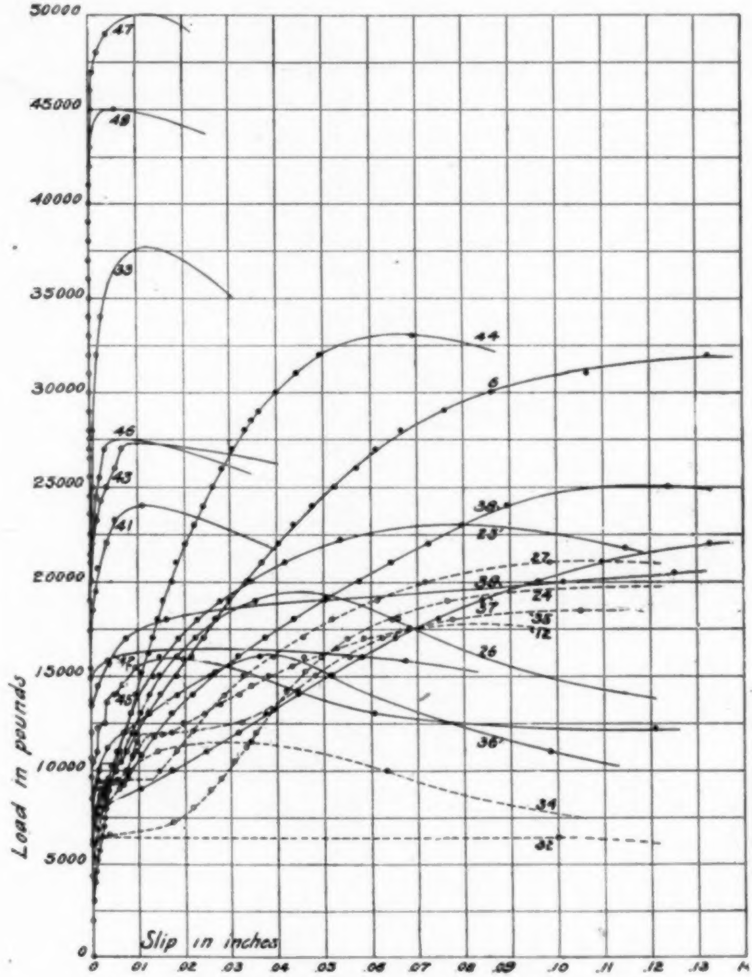


FIG. 10 LOAD-SLIP DIAGRAMS FROM 3-IN. BOILER TUBES ROLLED IN 1-IN. PLATES

was less easily measured in this arrangement but the eye could detect no movement of a fine scratch line at 15 000 lb. load. This corresponds to 2100 lb. per square inch hydraulic pressure in the box,

and the resistance at 1/100 in. slip was sufficient for the purposes of these experiments; this form was therefore adopted for a boiler of the Parker type designed for 300 lb. steam pressure with the feeling that the joint had as high a factor of safety within the slipping point

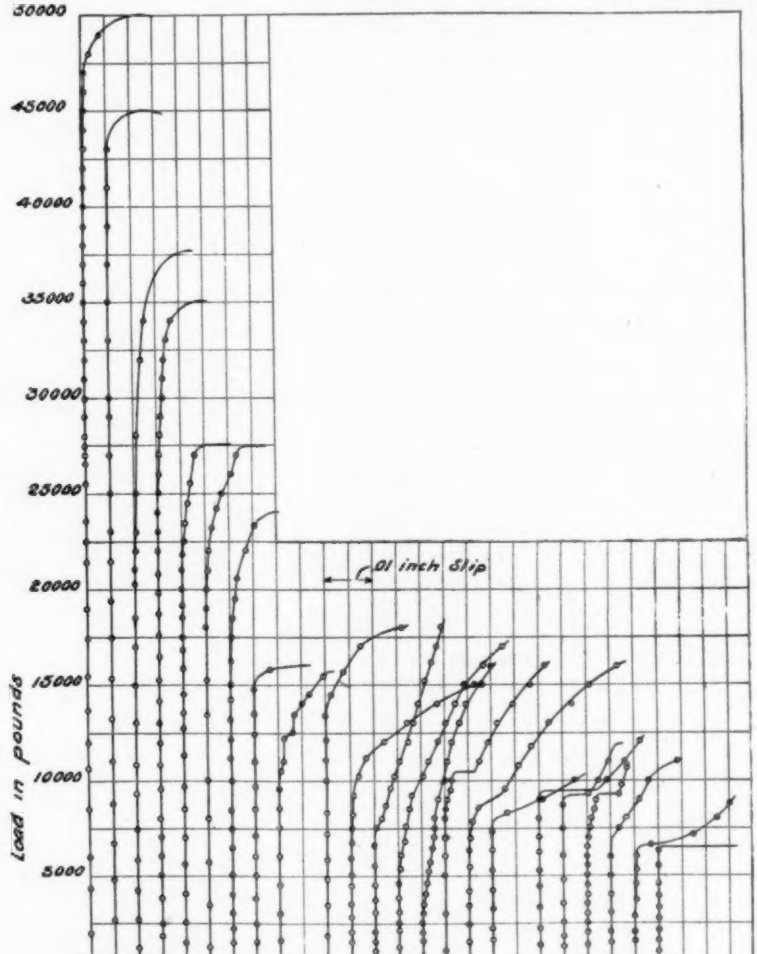


FIG. 11 LOAD-SLIP DIAGRAMS SHOWING INITIAL SLIP OF 3-IN. TUBES SHOWN IN FIG. 10, GROUPED ACCORDING TO TYPE OF TUBE HOLE

of the tube as had the rest of the boiler within the ultimate strength. Subsequent tests have shown better ways of making still stronger forms.

16 A study of the several tests made shows that in the usual machined joint the resistance to the first slipping comes from friction only. The friction is dependent on the normal pressure of the expanded tube against the sheet and this will be a maximum when the rolled metal of the tube is stressed to its elastic limit. The rolling of the metal elevates the elastic limit, but it takes a small amount of rolling to reach this maximum value. Further rolling reduces the thickness of the metal in play as fast as the elastic limit is exalted.

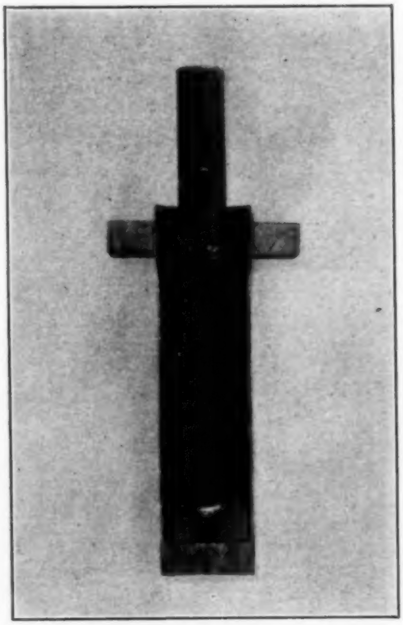


FIG. 12 SECTION OF TUBE NO. 47 LOADED BEYOND THE ELASTIC LIMIT

17 Assuming the elastic limit of the rolled metal at from 30 000 to 40 000 lb. the observed slipping point shows that the coefficient of friction must have been 35 to 26 per cent. The total friction per square inch of tube bearing area seems to be about 750 lb. in tube plates $\frac{5}{8}$ and one inch thick. It was observed that in straight and tapered holes wherever a high final strength was attained the metal of the tube was in some way abraded. Sometimes the sharp edge of the tube plate would shear a small ring from the metal of the tube and in other cases patches of the metal had apparently seized

and sheared. Computing the probable frictional resistance of these joints and adding the resistance of the sheared area shown on the tube gave a result agreeing closely with the observed ultimate strength of the joint as tested.

18 Most of these joints also showed a relatively high slipping point, suggesting the necessity of providing shearing resistance in addition to frictional resistance in order to obtain a high resistance to initial slip. Several forms were therefore made which provided

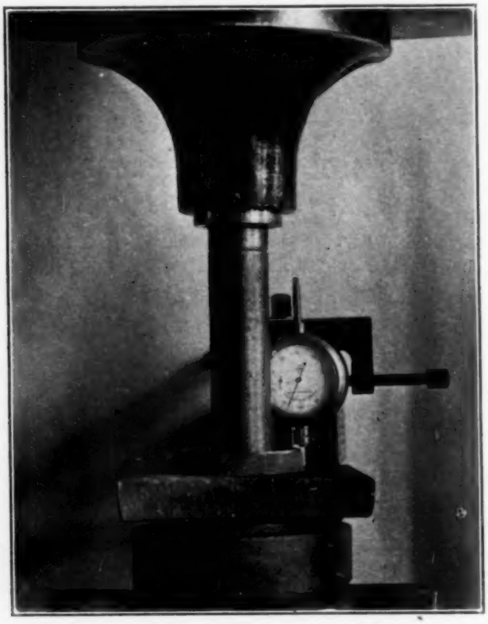


FIG. 13 METHOD OF APPLYING LOAD AND MEASURING SLIP

square shoulders in the tube sheet for the tube to be rolled against, with the object of making these several edges abrade the tube when it started to move. This serrating of the holes amounts to but little more than a "rough cut" in machining. Fig. 8 and 9 give the significant results obtained in several series of tests and Fig. 10 shows the same graphically. Fig. 11 shows the behavior of the tubes of each type up to a slight slip, thus showing the raising of the slipping point by the several methods.

19 To discover how much roughening was desirable a series of tests were made with straight holes, in which a shallow square thread was cut with a pitch of ten threads to the inch and from 0.005 to 0.020 in. deep. The tube ends were not flared. No. 45, 46, 47, 48 show the results from these serrated holes, in which it appears that the slipping point may be very greatly elevated by this means.

20 With serrations 0.005 in. deep the surface is barely roughened and the slipping occurs at 10 000 lb. This is increased successively to 16 000, 22 000 and 45 000 lb. by increasing the depth of the grooves to 0.007, 0.010, and 0.015 in., respectively. The elastic limit of the tube is reached in tension at about 34 000 lb. and this load was exceeded by a number of the tubes before there was any slip. Fig. 12 shows a section of tube 47 which resisted 50 000 pounds before slipping. The tube was stretched 0.25 in. in a length of 3 in. and reduced 0.11 in. in diameter.

21 This figure also shows the method of applying stress to all the tubes. A plug welded into one end of the tube carried a loose hemispherical seat for the end of a central column which received and transmitted the stress from the testing machine as shown in Fig. 13. The slip was measured by means of a dial micrometer fastened to the tube sheet and arranged to measure the movement of the projecting end of the tube.

22 In test 41 the hole in the tube sheet was serrated by rolling with an ordinary flue expander, the rolls of which were grooved 0.007 deep and 10 grooves to the inch. This method of serrating is easy and can be recommended where tubes are giving trouble from slipping and are required to carry an unusual load.

23 This tube has the slipping point raised to three or four times the usual value. It appears that with serrations about 0.015 inches deep giving an abutting area of about 1.4 sq. in. in a seat one inch wide that the maximum strength is reached as shown in tube 47.

SUMMARY

a The slipping point of a 3-in. twelve-gage Shelby cold drawn tube rolled into a straight smooth machined hole in a 1-in. sheet occurs with a pull of about 7000 lb.

b Various degrees of rolling do not greatly affect the point of initial slip.

c The frictional resistance of such tubes is about 750 lb. per square inch of tube-bearing area in sheets ⅝ inch and one inch thick.

d For a higher resistance to initial slip other resistance than friction must be depended upon.

e Serrating the tube seat in a straight machined hole by rolling or cutting square edged grooves about 0.01 in. deep and ten pitch will raise the slipping point to three or four times that in a smooth hole.

f It is possible to make a rolled joint that will offer a resistance beyond the elastic limit of the tube and remain tight.

SOME POSSIBILITIES OF THE GASOLENE TURBINE

By Frank C. Wagner, Terre Haute, Ind.
Member of the Society

In considering the possibilities of a gas turbine it has commonly been assumed that the gas should be burned with something near the theoretical quantity of air required for complete combustion, as is done in the explosion gas engine of the ordinary type. Under this condition the temperature of the gases when they strike the turbine wheel is so high that the metal of the wheel reaches a temperature at which its strength is seriously diminished.

2 It may be possible to pass water through the turbine wheel and keep down the temperature of the body of the wheel. But the blades, being long and thin, would become much hotter than the body of the wheel, and to pass water through the blades themselves would complicate the construction of the wheel enormously.

3 Two methods of reducing the temperature of the gases themselves are possible. One method is to use an excess of air in burning the gas or gasolene, sufficient to keep the temperature of the gases after expansion in the nozzles within safe limits. The other method is to inject a liquid, preferably water, into the gases. The liquid absorbs heat, becoming superheated vapor, and the vapor furnishes work during expansion. It is the purpose of this paper to compare the above methods of reducing the temperature of the gases, and especi-

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The professional papers contained in The Journal are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present. They are issued to the members in confidence, and with the understanding that they are not to be published even in abstract, until after they have been presented at a meeting. All papers are subject to revision.

ally to consider how such comparison is affected by variations in the efficiencies of the turbine and the air compressor.

4 The cycle of the type of gasolene turbine here considered is similar to that of the Diesel engine. The air is first compressed up to the maximum pressure. Fuel, either gas or oil, separately compressed, is then introduced and burned under pressure. The volume of the air is thereby expanded at constant pressure. After the burning is completed the hot gases expand adiabatically and the pressure drops. In the Diesel engine the expansion is incomplete, while in the

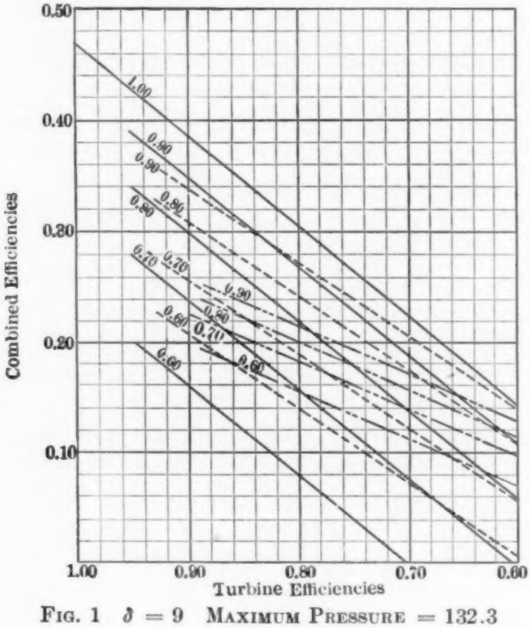

FIG. 1 $\delta = 9$ MAXIMUM PRESSURE = 132.3

gas turbine the expansion may be complete down to atmospheric pressure.

5 The efficiency of the above cycle may be readily found if both compression and expansion be assumed to be adiabatic. Let T_4 be the absolute temperature of the air just before compression; T_1 the temperature at the end of the compression; T_2 the temperature when the combustion is just completed; and T_3 the temperature at the end of the expansion. Assume the expansion to be complete. Then the ratio of the pressures at the extremities of an adiabatic change, sometimes called the compression pressure ratio, is the same for the

expansion line as for the compression line. Denote this ratio by ρ. Let C_p denote the specific heat of air at constant pressure, and γ the ratio of the specific heats.

6 Since the net mechanical work done equals the difference between the heat absorbed and the heat rejected during a complete cycle, it follows that the efficiency can be expressed thus:—

$$\text{Eff.} = \frac{C_p(T_2 - T_1) - C_p(T_3 - T_4)}{C_p(T_2 - T_1)}$$

$$= 1 - \frac{T_3 - T_4}{T_2 - T_1}$$

From the adiabatic relation,

$$\frac{T_1}{T_4} = \rho^{\frac{\gamma - 1}{\gamma}} = \frac{T_2}{T_3}$$

Consequently,

$$\text{Eff.} = 1 - \frac{T_4}{T_1} = 1 - \rho^{\frac{1-\gamma}{\gamma}}$$

7 The interesting feature of this expression for efficiency is that the theoretical efficiency depends *only upon the ratio of compression.* It does not depend on the maximum temperature reached. Consequently, from a theoretical standpoint it makes no difference whether the fuel is burned with the theoretical amount of air or with a considerable excess. If a sufficient excess of air is used the temperature of the gases when they strike the turbine blades can be brought down to a value for which the strength of steel retains a high value.

8 When practical efficiencies are considered, however, it is found that the proportion of air to fuel becomes important. Of the theoretical power that can be developed, only a fraction is actually converted into mechanical power. Consequently a much larger proportion of the available power must be consumed in compressing the air than is allowed in the theoretical expression for efficiency. The greater the proportion of air to fuel, the more will the practical efficiency fall off from the theoretical. The question arises whether with practicable mechanical efficiencies for the turbine and the compressor a sufficient excess of air can be used to bring down the temperature of the gases to a proper value and still give a reasonable efficiency for the complete operation.

9 The velocity stage type of turbine seems best suited for use as a gas turbine. The gases may be expanded completely in a nozzle of refractory material down to their lowest temperature before striking the wheel. The calculations which follow will be limited to this type of turbine.

10 The formula for theoretical efficiency indicates that high compressions are favorable to efficiency. To produce high compressions it is practically necessary to use two-stage or three-stage compressors. It occurred to the writer that it might be an advantage to use intercoolers between the stages of such compressors. Calculations have accordingly been made for the purpose of comparing the efficiencies obtainable with intercoolers and without them, with the general result, as shown in the tables, that while theoretically the best efficiency is obtained by adiabatic compression without intercoolers, yet with such values as are practically obtainable for the mechanical efficiencies of turbine and compressor the use of intercoolers is decidedly advantageous.

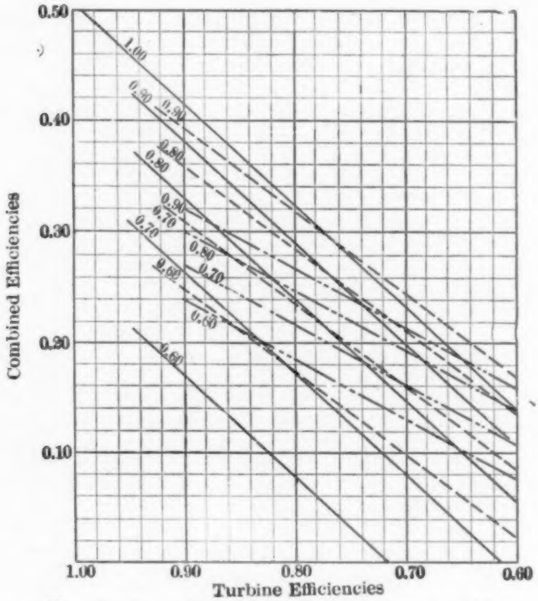

FIG. 2 $\delta = 16$ MAXIMUM PRESSURE = 235

11 Calculations have been made for a two-stage compressor having total compression pressure ratios of 9 and 16, and for a three-stage

compressor with a ratio of 27. The letter *a* is used when the compression is completely adiabatic, the letter *c* when the compression is adiabatic in each stage but the air is cooled between stages, and the letter *w* when water is injected.

12 It is assumed that the temperature of the air entering the compressor is 531 deg. fahr. abs., and also that each intercooler reduces the air to 531 deg. abs. The pressure of the air at the beginning of the compression is assumed to be 14.7 lb. per square inch abs., and the temperature of the gases leaving the expanding nozzle is assumed to be

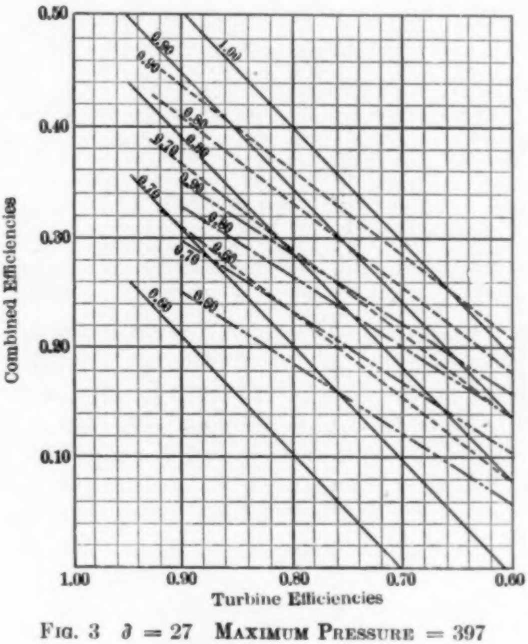

FIG. 3 $\partial = 27$ MAXIMUM PRESSURE = 397

1200 deg. fahr. abs., at which temperature the tensile strength of steel is about 10 per cent less than at ordinary temperatures. It is assumed that the fuel used is a gasolene containing 15 per cent hydrogen and 85 per cent carbon, and that its calorific value is 20 000 B.t.u. per pound. The work required to force the gasolene into the compressed air is relatively small and has been neglected. The value of γ taken was 1.4 for the air during compression. For the gases during expansion γ has been taken as 1.39. The value of the specific heat at constant pressure is taken as 0.2375 for the air and 0.25 for the gases.

13 The following is a sample calculation for a two-stage compressor with a pressure ratio of 3 in each stage:

Maximum pressure = 14.7 × 9 = 132.3 lb. per square inch.

(*a*) $T_1 = T_4 \times \rho^{\frac{2}{7}} = 531 \times 9^{\frac{2}{7}} = 995$ deg. abs.

(*c*) $T_1 = 531 \times 3^{\frac{2}{7}} = 727$ deg. abs.

$T_3 = 1200$ deg. fahr. abs.

$$T_2 = 1200 \times \frac{.39}{91.39} = 2225 \text{ deg.}$$

(*a*) Heat given to 1 lb. of gases = .25 (2225 − 995) = 307 B.t.u.
Gasolene used per lb. of air = 307/20 000 = 0.015 lb.
Heat given to 1.015 lb. of gases = 312 B.t.u.

(*c*) Heat given to 1 lb. of gases = 0.25 (2225 − 727) = 374 B.t.u.
Gasolene used per lb. of air = 0.019.
Heat given to 1.019 lb. of gases = 381 B.t.u.

(*a*) Heat equivalent of work required to compress 1 lb. of air = 0.2375 (995 − 531) = 110 B.t.u.

(*c*) Heat equivalent to compress 1 lb. of air = 0.2375 (727 − 531) × 2 = 93 B.t.u.

(*a*) Heat equivalent of work derived during expansion of 1.015 lb. of gases = 1.015 × 0.25 (2225 − 1200) = 260 B.t.u.

(*c*) Heat equivalent of work derived during expansion of 1.019 lb. of gases = 1.019 × 0.25 (2225 − 1200) = 261 B.t.u.

(*a*) Heat required to vaporize 0.015 lb. of gasolene and heat it from 531 deg. to 995 deg. = [.5(995 − 531) + 240] × 0.015 = 472 × 0.015 = 7 B.t.u.

(*c*) Heat required to vaporize 0.019 lb. of gasolene and heat it from 531 deg. to 727 deg. = 0.019 × [0.5 (727 − 531) − 240] = 338 × 0.019 = 6 B.t.u.

$$(a) \text{ Theoretical efficiency } = \frac{260 - 110}{312 + 7} = 0.47$$

$$(c) \text{ Theoretical efficiency } = \frac{261 - 93}{381 + 6} = 0.43$$

14 For a mechanical efficiency of the turbine of 0.65 and of the compressor of 0.85, the combined efficiencies will be:

$$(a) \text{ Eff. } = \frac{0.65 \times 260 - 110 \div 0.85}{319} = 0.13$$

$$(c) \text{ Eff. } = \frac{0.65 \times 261 - 93 \div 0.85}{387} = 0.16$$

15 The corresponding calculation for water cooling follows. The heat absorbed by the injected water has been calculated from the values for the specific heat of superheated steam given in a recent paper by Professor Thomas.

Temperature at end of compression (*a*) = 995 deg.
Temperature at end of compression (*c*) = 727 deg.
Allow 19 lb. of air to 1 lb. of gasolene.
Theoretical temp. of gases after burning

$$(a) = \frac{20\,000 - 472}{20 \times .25} + 995 = 4900 \text{ deg.}$$

Theoretical temp. of gases after burning

$$(c) = \frac{20\,000 - 338}{20 \times .25} + 727 = 4659 \text{ deg.}$$

Temperature at beginning of expansion = 2225 deg.
B.t.u. required to convert 1 lb. of water at 70 deg. fahr. into superheated steam at 2225 deg. and 132.3 lb. pressure = 1188.2 − 38 + 142 + 0.47 (2225 − 1079) = 1830
Water required per pound of gas

$$(a) = \frac{(4900 - 2225) \times 0.25}{1830} = 0.37$$

Water required per pound of gas

$$(c) = \frac{(4659 - 2225) \times 0.25}{1830} = 0.33$$

Work done by 1 lb. of gas = 256 B.t.u.
Temperature of steam at end of expansion = $2225 \div 0.9^{\frac{0.3}{1.3}}$ = 1340 deg.
Work done by superheated steam (*a*) = 0.37 × 0.47 (2225 − 1340) = 154 B.t.u.
Work done by superheated steam (*c*) = 0.33 × 0.47 (2225 − 1340) = 138 B.t.u.
Heat furnished by $\frac{1}{20}$ lb. of gasolene = 1000 B.t.u.
Eff. (theoretical)

$$(a) = \frac{256 + 154 - 19/20 \times 110}{1000} = \frac{410 - 105}{1000} = 0.305$$

Eff. (theoretical)

$$(c) = \frac{256 + 138 - 19/20 \times 93}{1000} = \frac{394 - 88}{1000} = 0.306$$

16 A calculation of the total efficiencies for various efficiencies of turbine and compressor shows that a combination of water injection and intercooling gives a slightly higher total efficiency than water injection without intercooling. It is not probable that both would be used in the same machine and consequently the calculations have been limited to the case of water injection with true adiabatic compression.

17 The results have been arranged in the form of tables and also plotted in the accompanying diagrams. If the turbine efficiencies be chosen as abscissas and the total efficiencies as ordinates, then for a fixed compressor efficiency the relation will be expressed by a straight line. Lines have been drawn representing compressor efficiencies of 90, 80, 70, and 60 per cent. Full lines represent cooling by excess of air and true adiabatic compression; dotted lines, cooling by excess of air and cooled compression; broken lines, cooling by water injection and adiabatic compression.

TABLE 1 TOTAL EFFICIENCIES FOR VARIOUS MECHANICAL EFFICIENCIES
$\rho = 9$; Maximum Pressure = 132.2 lb. per square inch abs.

Compressor Efficiency	TURBINE EFFICIENCIES														
	1.00			0.90			0.80			0.70			0.60		
	a	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*
1.00	0.47	0.43	0.30												
0.90				0.35	0.34	0.26	0.27	0.27	0.23	0.19	0.21	0.17	0.11	0.14	0.13
0.80				0.30	0.31	0.25	0.22	0.24	0.22	0.14	0.17	0.16	0.06	0.11	0.12
0.70				0.24	0.26	0.23	0.16	0.20	0.19	0.08	0.13	0.14	0.00	0.06	0.10
0.60				0.16	0.21	0.20	0.08	0.14	0.16	0.00	0.07	0.12	0.00	0.00	0.07

TABLE 2 TOTAL EFFICIENCIES FOR VARIOUS MECHANICAL EFFICIENCIES
$\rho = 16$; Maximum Pressure = 235 lb. per square inch abs.

Compressor Efficiency	TURBINE EFFICIENCIES														
	1.00			0.90			0.80			0.70			0.60		
	a	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*
1.00	0.52	0.51	0.39												
0.90				0.38	0.39	0.32	0.30	0.32	0.26	0.20	0.24	0.21	0.12	0.17	0.16
0.80				0.33	0.36	0.30	0.24	0.28	0.24	0.15	0.21	0.19	0.06	0.13	0.14
0.70				0.26	0.31	0.27	0.18	0.23	0.22	0.09	0.15	0.16	0.00	0.08	0.11
0.60				0.17	0.25	0.24	0.08	0.17	0.18	0.00	0.10	0.13	0.00	0.02	0.08

TABLE 3 TOTAL EFFICIENCIES FOR VARIOUS MECHANICAL EFFICIENCIES
$\rho = 27$; Maximum Pressure = 397 lb. per square inch abs.

Compressor Efficiency	TURBINE EFFICIENCIES														
	1.00			0.90			0.80			0.70			0.60		
	a	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*
1.00	0.61	0.55	0.43												
0.90				0.45	0.44	0.35	0.35	0.36	0.29	0.24	0.29	0.23	0.14	0.21	0.16
0.80				0.39	0.41	0.33	0.29	0.33	0.26	0.18	0.25	0.20	0.08	0.18	0.14
0.70				0.31	0.37	0.29	0.20	0.29	0.23	0.10	0.21	0.16	0.00	0.13	0.11
0.60				0.21	0.31	0.25	0.10	0.23	0.19	0.00	0.15	0.12	0.00	0.08	0.06

18 An inspection of these tables and diagrams shows that for all values of the mechanical efficiencies that seem obtainable at present, true adiabatic compression gives a lower total efficiency than either intercooling or water injection.

19 It also appears that water injection gives a higher efficiency under some conditions than air dilution, while under other conditions the reverse is true. The diagrams show this very clearly. The slope of the total efficiency lines is such that the total efficiency line for water injection corresponding to a certain compressor efficiency may intersect the line for air dilution with intercooling corresponding to the same compressor efficiency. For instance, in the diagram for a compression ratio of 16, the total efficiency line for water injection corresponding to 70 per cent compressor efficiency crosses the 70 per cent line for air dilution with intercooling at 74. Consequently, when the compressor efficiency is 70 per cent, the total efficiency for water injection is less than for air dilution with intercooling if the turbine efficiency is greater than 74 per cent. If the turbine efficiency is less than 74 per cent, water injection shows the greater efficiency.

20 Comparing the diagrams for different compression ratios, not only are the total efficiencies greater for the higher pressures, but the relative effects of the different methods employed for keeping down the temperature of the gases upon the total efficiencies change decidedly. For instance, in the diagram for $\rho = 16$, the 70 per cent lines for water injection and for intercooling intersect at a turbine efficiency of 74 per cent, while in the diagram for $\rho = 27$, the corresponding lines do not intersect within the limits of the diagram, showing in the latter case that air dilution with intercooling is the more efficient for all values of turbine efficiency included in the diagram.

21 The air used per pound of gasolene in the different cases is as follows:

For $\rho = 9$ condition (*a*) ....66 lb.
For $\rho = 9$ condition (*c*) ....52 lb.
For $\rho = 16$ condition (*a*)....................52 lb.
For $\rho = 16$ condition (*c*)....................43 lb.
For $\rho = 27$ condition (*a*)....................47 lb.
For $\rho = 27$ condition (*c*)....................34 lb.
For all values of ρ (*w*)......................19 lb.

22 What can be expected of the gasolene turbine in practice?

23 Air compressors of the piston type have been constructed which give a mechanical efficiency of 85 per cent. The best mechanical efficiency obtained with steam turbines is in the neighborhood of 65 per cent. Whether a velocity stage gas turbine of equal efficiency is possible can only be determined by actual trial. Some of the points of difference are as follows.

24 In the steam turbine, the wheel revolves in gaseous mediums varying from a considerable density at the higher pressures to a very small density in the vacuum at the exhaust end. In the gas turbine, the gaseous medium is at atmospheric pressure, but on account of its high temperature the density will be only a little more than a third of that of air under ordinary atmospheric conditions. It is quite possible that the wheel friction will be no greater on the whole for a gas turbine than for the best steam turbine.

25 The velocity of the gases leaving the expansion nozzle for a compression ratio of 27 would be about 4600 ft. per second, which is much higher than occurs in steam turbine practice. The effect of friction at such high velocities is yet to be determined. The experiments quoted by Professor Thomas in his book on Steam Turbines indicate that up to 220 lb. per square inch pressure the percentage of friction loss in a properly shaped nozzle diminishes with increase of pressure. If this law continues, the use of high jet velocities may not detract from the efficiency.

26 It seems, therefore, within the range of possibilities to construct a gas turbine giving an efficiency of 60 per cent, and a three-stage air compressor of 85 per cent efficiency. Referring to Fig. 3, the combined efficiency for air dilution with intercooling is found to be 19.5 per cent, and for water injection, 15 per cent.

27 In Bulletin 191 of the U. S. Department of Agriculture, Lucke and Woodward detail tests of engines using gasolene and alcohol.

The smallest fuel consumption with gasolene was about 0.7 lb. of gasolene per brake horse power, obtained only with the most perfect adjustment in a very few tests. The average fuel consumption was nearer 1.25 lb. which probably represents more nearly the average practice. A fuel consumption of 0.7 lb. of gasolene per horse power corresponds to an efficiency of about 18 per cent, while 1.25 lb. corresponds to 10 per cent efficiency.

28 The gasolene turbine appears to offer advantages in reliability, comparative simplicity of adjustments, and freedom from annoying troubles as compared with the explosion engine. Whether it can compete with the latter in power developed per unit of weight remains to be determined. A further advantage over the explosion engine is that the gasoline turbine can burn crude oil, which is a cheaper fuel.

SALT MANUFACTURE

MECHANICAL METHODS AND ENGINEERING FEATURES OF LARGE SALT PLANTS

By George E. Willcox, Saginaw, Mich.

Member of the Society

The literature readily available on the subject of salt manufacture is not extensive, and is for the most part contained in volumes devoted principally to other subjects, such for instance as geological reports of the various States, besides a number of pamphlets that have appeared from time to time as the result of special investigations of specific problems relating to salt manufacture. These pamphlets and reports have treated the question in general from the standpoint of the chemist or the geologist rather than that of the mechanical engineer.

2 It is the purpose of this paper to note from a mechanical engineer's point of view a few of the more recent developments in the mechanical methods and appliances of some of the large salt plants. Reference will be made solely to plants operated by what is known as the steam grainer system, as distinguished from the vacuum pan system, and the solar or open air system.

GENERAL ARRANGEMENT OF A GRAINER PLANT

3 Since the nature of the brine obtainable determines the treatment necessary before the actual process of evaporation begins, the arrangement of the component parts of a grainer plant for the manufacture of salt varies in different localities. The majority

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of them in America are, however, arranged somewhat as in Fig. 1, which is a map of a salt plant having ten grainers built of reinforced concrete with a total producing capacity of approximately 1000 bbl., or about 140 tons of salt per 24 hours. It may be of interest that this plant operates by exhaust steam of less than 2 lb. pressure. It operates 24 hr. a day. Six men are employed at the plant, four on the day shift and two at night. These men do all the work, including pumping, liming and settling the brine, making the salt and delivering it on the storehouse floor. Fig. 2 is a bird's-eye view of such a plant.

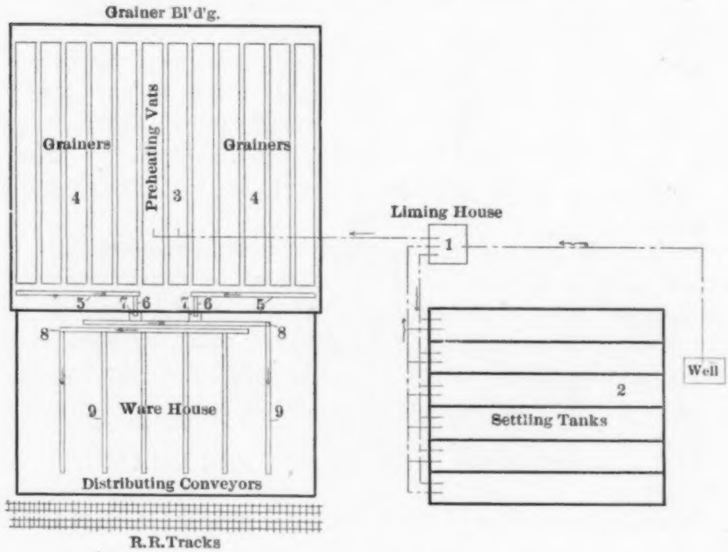

FIG. 1 MAP OF SALT PLANT

4 In general, the mode of operation is as follows: Brine is first pumped from the wells into a liming house (Fig. 1), where it is (1) mixed with a suitable proportion of slaked lime to precipitate the iron contained in it. After liming, the brine is pumped into settling tanks (2), where it remains until perfectly clear, usually 24 to 48 hr. or longer being required for the settling. From the settler it is drawn into large pre-heating vats (3) located in the grainer building, and there heated by means of submerged steam pipes. From the pre-heating vats the brine is drawn into the grainers (4), where it is evaporated by steam pipes submerged in the brine.

5 The salt produced by each grainer is moved along the grainer bottom and up an incline at its front end by an automatic "salt raker" and then dropped into a collecting conveyor (5). Thence it is carried by a conveyor (6) to the top of a bucket elevator (7) that hoists it to the top of the storehouse. The elevator discharges at its top on either of a pair of conveyors running in opposite directions (8), located just beneath the storehouse roof. From the conveyor (8) the salt is delivered to any one of a series of distributing conveyors

FIG. 2 BIRD'S-EYE VIEW OF SALT PLANT

(9) and dropped therefrom to the warehouse floor. The height of conveyors (9) and their distance apart is such that nearly the entire storage space of the warehouse can be filled with salt without shoveling.

SALT GRAINERS OF REINFORCED CONCRETE

6 In years gone by white pine was available for the construction of grainers and was almost universally used. It withstood the action of the hot brine admirably, was easily worked, did not shrink to any great extent as do nearly all other woods when exposed to hot brine

and when properly calked with oakum was capable of giving good service for five years or more.

7 With the decline of the white pine supply, however, came a demand for some other material than wood from which to build grainers and attention was directed toward reinforced concrete.

8 The ordinary salt grainer is a pan usually 150 ft. long by 12 ft. wide by 2 ft. deep equipped with steam pipes. This pan is often called upon to undergo considerable changes in temperature, varying in extreme cases from 40 to 185 deg. fahr. and back again to 40 deg. It must of course remain brine-tight under all conditions.

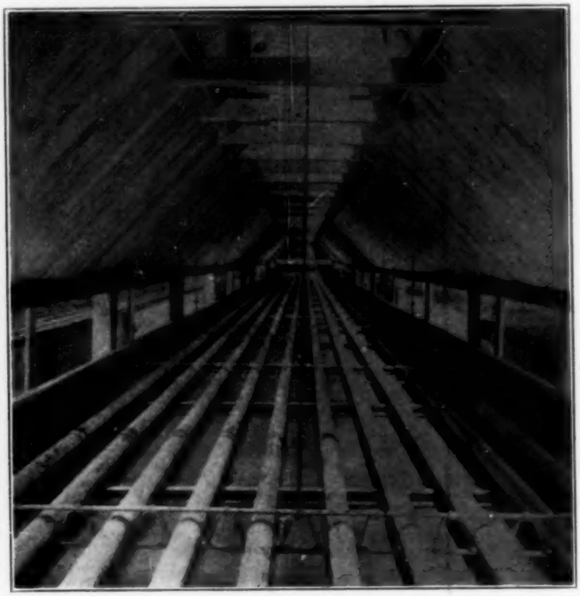

Fig. 3 Monolithic Concrete Grainers

9 A method of construction that has proven satisfactory to stand the strain incident to such temperature variation is shown in Fig. 3. These grainers are monolithic, no expansion joints being used. They rest on a hard flat bed of rammed sand, giving a uniform support throughout the grainer bottom and reducing radiation loss.

10 When the brine is warmed from say 40 to about 180 deg. fahr., the concrete grainer expands approximately 1½ in. in its length of 150 ft. All the grainers do not expand alike, however. When cooled

they contract to their original position. After nearly 3 years of constant use they are in first-class condition and brine-tight. Concrete is an excellent material for reducing radiation loss; in fact these grainers continue to make salt for three or four days after the steam is shut off.

DETAILS OF CONCRETE GRAINER CONSTRUCTION

11 Their construction is shown in detail in Fig. 4. The grainer walls are 6 in. thick and the bottom 4 in. The reinforcing bars are ¼ in. corrugated. Transverse the grainer the bars are laid 4 in. on centers. Alternate transverse bars extend down one wall, bend at the

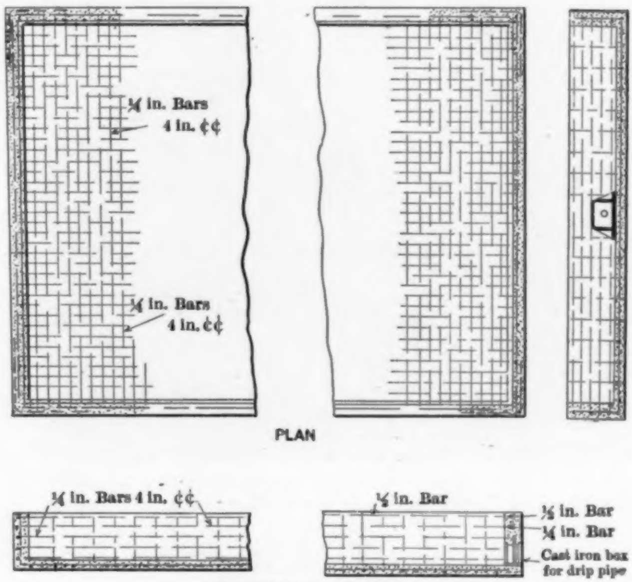

FIG. 4 DETAILS OF GRAINER CONSTRUCTION

juncture of the wall and bottom, and run imbedded in the bottom to the base of the opposite wall. The longitudinal bars are also spaced 4 in. apart and at the ends of the grainer are bent up to form vertical reinforcement. The side and end walls have horizontal bars spaced 4 in. apart, and near the top edges of the walls is a ½ in. bar extending entirely around the grainer. Fig. 5 shows a grainer under construction.

12 The concrete used was a mixture of Portland cement, sand and gravel. The lower 2 in. of the grainer bottom was in the proportion of one to six, being 1 cu. ft. of cement to 2 cu. ft. of sand and 4 cu. ft. of gravel. The top 2 in. was 1 cu. ft. of cement to 3 cu. ft. of sand. The side walls were 1 cu. ft. of cement to 1 cu. ft. of sand and 1 cu. ft. of gravel. All the concrete was mixed very wet, so that it would run off a shovel and was poured into place. No water-proofing method was used in the construction of the grainers other than a gentle spudding of the side walls next to the forms with a thin bladed spud immediately after the concrete was poured. The bottom was leveled by striking off with a strike

FIG. 5 LAYING CONCRETE IN GRAINER BOTTOM AND WALLS

guided at its ends on rails spiked to the sides of the wall forms, and the surface was finished by troweling. Openings for drip pipes, etc., were made by embedding cast iron boxes provided with anchor wings into the concrete, Fig. 4, and fitting these boxes with glands and packing boxes.

13 After becoming accustomed to the work by building two or three grainers, a crew of twelve men can place the reinforcing bars and pour the concrete for a grainer of the size given in 9 hr.

14 The first few grainers at this plant were built in the open air, and as the sun was very hot they were covered by a canvas tent, shown in Fig. 6, which was later dispensed with when the building

construction was far enough along to protect the fresh concrete. The same grainer with the forms removed is shown in Fig. 7.

15 The life of these reinforced concrete grainers has not been determined, but after three years' use the indications are that they are good for many years. If the hot brine shows a deleterious effect on the concrete after long use, the side walls will be lined with flat slabs of vitrified tile, but the necessity has not arisen up to this time.

RAKERS

16 In the process of evaporation, the salt accumulates on the grainer bottom and unless removed will continue to accumulate

FIG. 6 GRAINER COVERED WITH TENT FOR PROTECTION OF CONCRETE WHILE SETTING

until the grainer is nearly full of salt. It is necessary to "lift" the salt, either by hand when the grainer is nearly filled or by some automatic means as fast as it is formed. The automatic continuous method is the one now generally adopted in grainer plants throughout the United States, not only because it is less expensive than hand lifting, but also because of the difficulty of securing laborers willing to undergo the hard manual labor in the hot steamy atmosphere of a salt plant.

17 Various types of machines, generally designated as "salt rakers," have from time to time been developed for this purpose. They all belong in the class of conveyors, their sole purpose being to

rake the salt along the grainer bottom and deliver it up an incline located at one end of the grainer. Some peculiar conditions met with in designing machines for this class of work are of interest from a mechanical point of view. Salt rakers, whatever their construction, must be capable of keeping the grainer bottom clear; that is, they must sweep a space of about 150 x 12 ft. continuously, and deliver the salt up an incline, giving the salt an opportunity to drain before being pushed over into the conveyors by which it is transported to the warehouse. The size of the raker practically necessitates the use of iron or steel in its construction, but iron or steel deteriorates

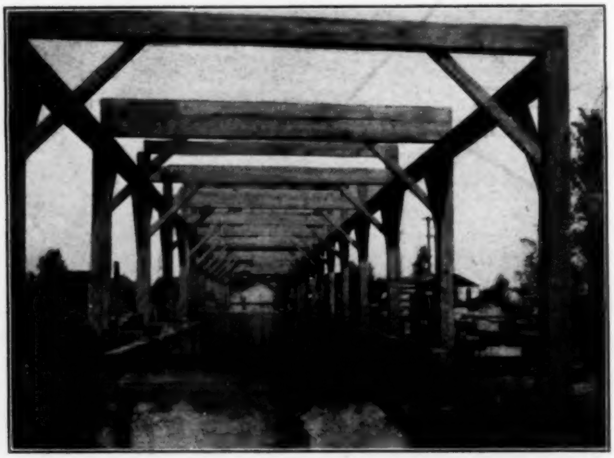

Fig. 7 Forms and Tent Removed Grainer Filled with Water and First Bent of Building in Place

rapidly if exposed to the steamy atmosphere of a salt grainer. In fact, it is very common for a half-inch bar of steel to be eaten entirely through in the space of a few months. This corrosion of the steel introduces another element of danger, namely, discolored salt. If a bar of iron or steel is allowed to project down into a salt grainer, a bunch of salt will be formed at the brine level and continue to grow until when it is displaced from some cause that part of the salt in contact with the iron is discolored with iron rust. A very small amount of iron rust will result in streaks of red through the salt piles in the warehouse, depreciating the value of the product.

18 Chains heretofore used in the design of salt rakers have been generally abandoned on account of the liability of breakage. Wheels

have been avoided as far as possible because of the excessive wear on their treads when working in an atmosphere of salt vapor. A chilled cast-iron wheel 8 in. in diameter by 4 in. face, running on a steel track and carrying a load that would not be at all excessive under ordinary conditions, will wear away on the tread during a period of three or four months in the steamy atmosphere of a salt plant to such an extent that there will be practically nothing left except the babbited core and the flanges. Such rapid wear seems to be due, first, to corrosion of the tread, and then to the wearing away of the rust so formed by continued rolling of the wheel on its track. Wheels are therefore to be avoided.

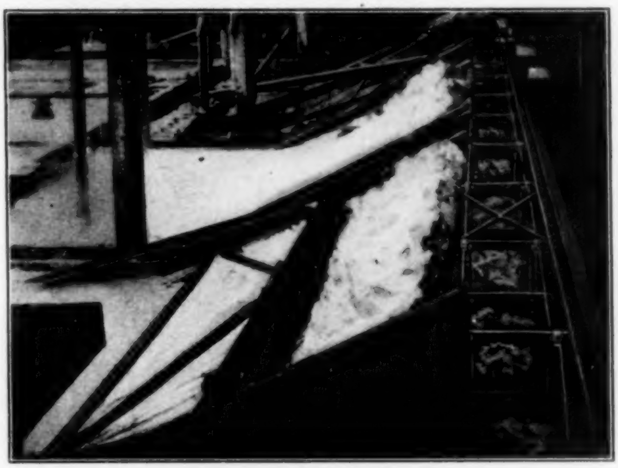

Fig. 8 Sweeping Action of Automatic Salt Raker

19 Another mechanical difficulty in designing a raker for this purpose lies in the fact that the brine surface should be as clear and unobstructed as possible, so that the salt maker can judge from its appearance the condition and grain of the salt that is being produced. Overhead framework is therefore an undesirable feature in raker construction.

20 After much experimenting, passing through many stages of development, the automatic salt raker of today has taken the form shown in Fig. 9 and 19, which are respectively a top plan view and a longitudinal elevation of a grainer equipped with a raker. The raker is driven by a hydraulic cylinder located in front of the grainer.

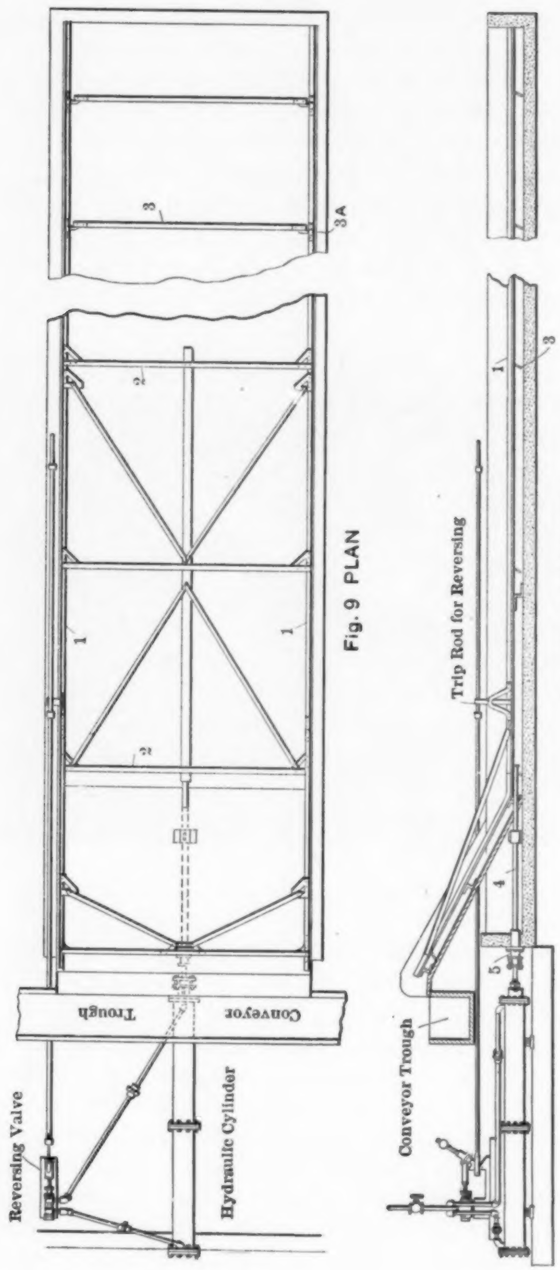

FIG. 9 AND 10 AUTOMATIC SALT RAKER WITH HYDRAULIC DRIVE

21 The sweeps or scrapers of this machine were shown in Fig. 3, underneath the pipes, and the manner in which the salt is pushed up out of the grainer is shown in Fig. 8. The sweeps, by a back-and-forth or reciprocating movement, operate to push the salt toward the end of the grainer on the forward stroke and to feather on the back stroke, forcing the salt with a step-by-step movement along the bottom of the grainer and up the incline.

22 The raker is submerged in the brine and operates underneath the grainer pipes where the air can not get to it except when the grainer is empty. By this simple expedient, corrosion is reduced to the minimum and no difficulty is experienced from red salt. The raker, Fig. 9 and 10, consists essentially of a frame-work comprising two steel angles (1) located within the grainer near its bottom and adjacent to the side walls. At intervals these two angles are connected by cross braces (2) and the frame-work so formed carries a series of feathering scraper blades (3) extending transverse the grainer and supported at their two ends on the two side angles by means of horizontally-projecting rocking pivots or fingers (3A).

23 The scrapers are usually spaced about 8 ft. apart and the entire raker has a back-and-forth movement of about 9 ft., so that each blade travels about 1 ft. ahead of the initial position of the next blade in front. The salt is thus gradually passed step by step to the front of the grainer and up the incline.

24 Hot brine makes an excellent lubricant, and therefore the only support needed for the side angles is a series of flat cast-iron shoes spaced at suitable intervals along the grainer bottom, and it is on the tops of these shoes that the side angles (1) slide back and forth.

25 The rakers are actuated by a variety of different devices, the hydraulic cylinder, however, affording the best chance for regulation and giving the least trouble in practice. The piston rod (4) passes into the grainer through a stuffing box (5) in which are several rings of metallic packing. The cylinder is usually about 8 in. in diameter by 9 ft. stroke. It makes a stroke in about 2 min., bringing up a load of salt every 4 or 5 min. The cylinder operates at a water pressure of about 80 lb., supplied usually by a steam pump or a motor-driven triplex plunger pump.

26 In the plant illustrated, 10 rakers and 2 reciprocating salt conveyors are operated by one pump. The cylinder water is used repeatedly by returning the discharge from the cylinders to a tank from which the pump takes its suction.

BELT CONVEYORS

27 In conveying the salt from the grainers to the warehouse and discharging it on the warehouse floor many difficulties have been encountered not ordinarily met with in the conveying of materials. On a dry day the salt may be apparently dry and almost similar to granulated sugar in its behavior in the conveyors, but with increased humidity in the weather, the salt becomes soggy and on a very damp or foggy day will even drop brine from the conveyor. If the conveyor is a belt, the salt can be readily cleaned from it on a dry day by means of a diagonal scraper of plate glass, but on a wet day it will stick to the belt so that it is exceedingly difficult to remove it by any cleaning device. Various kinds of scrapers and rotary brushes have been tried but failed.

28 Another difficulty encountered with belt conveyors having iron rollers is excessive corrosion, the under side of the belt becoming covered with iron rust that sooner or later under the sweating of the salt drops rusty water and pieces of discolored salt on the salt piles. It has been found advisable to dispense with iron as much as possible in the construction of belt conveyors for carrying salt, and in the author's opinion, the most satisfactory arrangement is an idler roller made of pepridge, about 5 in. in diameter and two or three inches longer than the width of the belt. Through the roller is passed a cold rolled shaft, the ends projecting about 6 in. beyond the ends of the roller. The roller is then centered and turned in a lathe.

29 The bearings for the rollers are simply blocks of well seasoned hard maple. Ordinary cup grease is used as lubricant. Bearings of this kind have been run constantly for about three years without serious indications of wear.

30 One difficulty, however, that seems inherent in the use of conveyor belts for handling salt that must be moved in a continuous stream and where the belt is to operate continuously for a long period of time is this: the pepridge rollers reduce in diameter somewhat under the wearing action of the belt and have to be renewed occasionally; but this is not so serious a matter as the discoloration of the salt by particles dropping from the conveyor upon the salt pile. The exact cause of the accumulation of dirty salt along the edges of the belt and the winding of streaks of black salt around the peripheries of the rollers just at the edges of the belt is difficult to account for even after careful investigation, except on the theory

that the moist belt passing through the air in course of a day's run picks up from the air particles of dirt and soot that ultimately work to the edges and wind around the rollers until they have accumulated sufficiently to fly off and drop into the salt pile below.

31 Analysis of such particles showed no traces of rubber and the fact that the belt will run a year or more before wearing out sufficiently to necessitate renewal indicates that the dirt does not come from the belt and probably not much of it comes from the wearing of the wooden rollers. It is not practicable to enclose a belt conveyor in an air-tight box; a different style of conveyor has there-

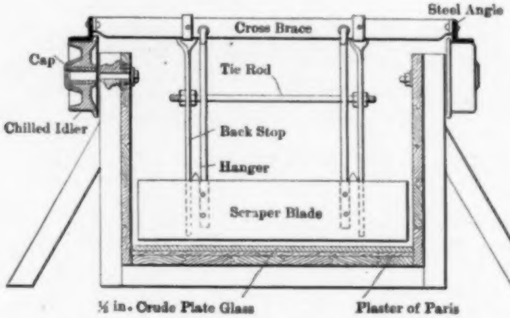

Fig. 11 Transverse Section of Reciprocating Conveyor

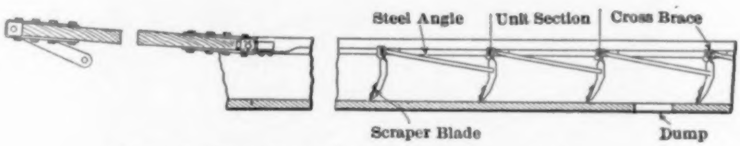

Fig. 12 Side View of Reciprocating Conveyor

fore been adopted for handling salt under the conditions named, i. e., where a small stream of salt must be taken continuously from the grainer plant and delivered on the warehouse floor. This trouble together with rapid depreciation make belts undesirable. These objections apply to continuous delivery of salt in a small stream and not to belts used for cargo loading, where a large quantity must be transported in a short space of time.

RECIPROCATING CONVEYORS

32 A form of conveyor that has been found to be well suited for the continuous handling of salt is shown in Fig. 11, which is a trans-

verse section of a conveyor trough, and in Fig. 12, which is a longitudinal section showing the driving pitman and also the slot through which the salt drops from the conveyor. In this conveyor the scraper blades are usually spaced about 3 ft. apart and the conveyor has a back-and-forth movement of about 5 ft. The principle of operation is the same as that of the rakers previously described.

33 In Fig. 11, the steel side angles of the conveyor are shown supported on idlers with chilled rims. It is not absolutely necessary to use these idlers, as the conveyor works very well if the steel side angles are supported inside the conveyor trough instead of outside

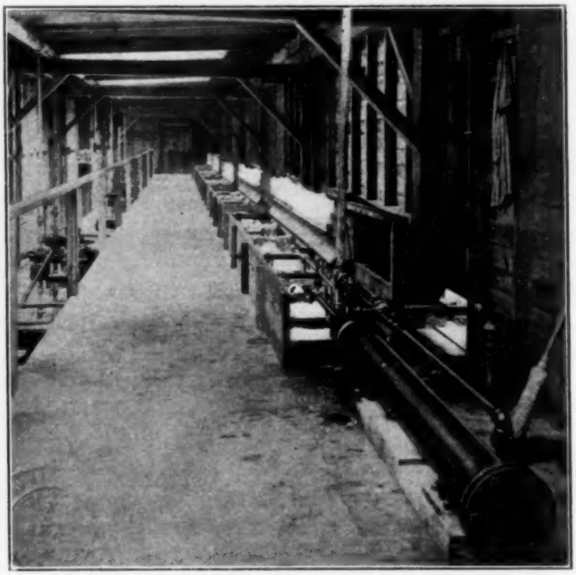

Fig. 13 Conveyor Driven by Hydraulic Cylinder

as shown, and allowed to slide back and forth on angle iron brackets spaced about 6 ft. apart along the trough. The salt dropping into the conveyor from above acts as a lubricant between the two rubbing surfaces. This latter construction has the advantages of cheapness and simplicity, but its disadvantage is the greater liability of particles of dirt getting into the salt. It has been found in practice, however, that the latter disadvantage is more apparent than real.

34 It is preferable to make the scraper blades of well seasoned hard maple but in some instances they are made of $\frac{1}{8}$ by 6 in. band steel. This type of conveyor must of course be thoroughly galvanized to reduce corrosion as much as possible.

35 The scraper blades and their braces should be arranged in unit sections, as indicated in Fig. 12, so the conveyors can readily be made of any length desired. Such standardization permits reversing the scraping direction of one part of the conveyor if necessary. This type of conveyor has one important advantage over a continuous

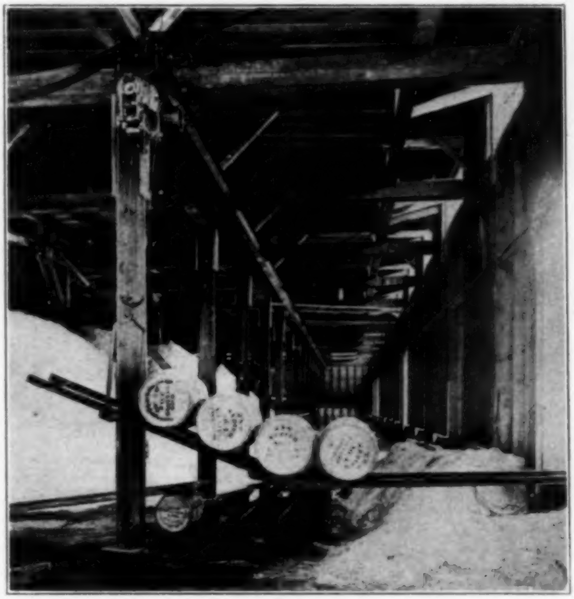

FIG. 14 APPARATUS FOR LOADING UNDER SPECIAL CONDITIONS

belt conveyor in that it will scrape in two directions at the same time, if part of the blades operate in one direction and part opposite.

36 The bottom of the trough for a conveyor of this type should be as smooth as possible and probably the best lining for the purpose is $\frac{1}{2}$ in. crude plate glass, that is, plate glass which has not been ground or polished. It can be had from any plate glass works at approximately $0.30 per square foot, and is easily laid by rubbing it into a bed of plaster-of-paris.

37 There is of course a limit to the length that is practicable for a conveyor of this kind, but for salt plant purposes 200 ft. is not

excessive. Such a conveyor, with side angles made of 2 in. by 2 in. by $\frac{1}{4}$ in. angle, blades of $\frac{1}{8}$ in. by 6 in. steel, 2 ft. wide, has been in continuous operation for about four years taking the salt from eleven grainers, each 13 ft. wide by 176 ft. long. The particular conveyor referred to is about 200 ft. long, and the bottom of the trough is lined with hard maple. If it were lined with glass it could probably be successfully operated at a length of about 300 ft. It is driven by a hydraulic cylinder as shown in Fig. 13, or by a crank and pitman, as in Fig. 12. It is probable that this form of conveyor may have other uses than in salt making.

APPARATUS FOR LOADING SALT BARRELS INTO CARS

38 An apparatus found very effective in salt plants for loading barrels into cars, and of interest in connection with locations where

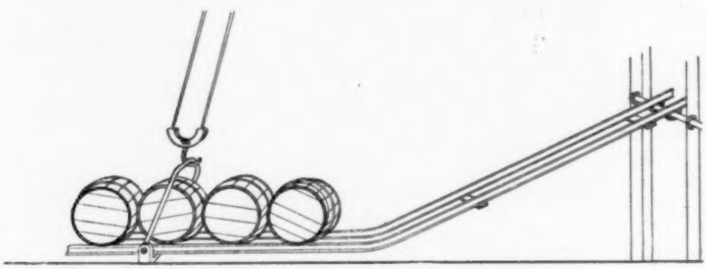

FIG. 15 BARRELS ON LOADER READY FOR LIFTING

the car platform is higher than the storehouse floor, is illustrated in Fig. 14. This apparatus was devised to meet a condition where great numbers of barrels each containing 280 lb. of salt had to be loaded from the storehouse floor into box cars. Owing to the presence of quick-sand, the enormous loads to be carried and other considerations, it was found necessary in this particular plant to put the storehouse floor directly upon the ground, and as it was impracticable on account of existing grades to depress the railroad track alongside the storehouse, the car platforms are about 4 ft. above the warehouse floor.

39 It is customary in loading a car with salt barrels to put in first a tier of barrels standing on end and then on top of them a tier of barrels lying on their bilges. An overhead I-beam extending the whole length of the storehouse and paralleling the railroad track,

was provided with a traveling electric hoist. Each loading door of the storehouse was provided with a pair of sockets to receive the rock-shaft of the loading device. Two pieces of light tee-rail are

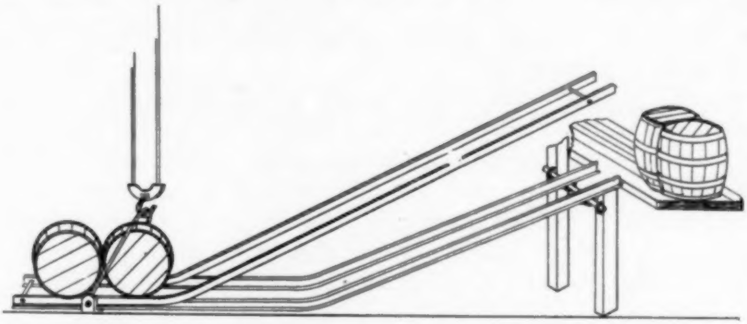

Fig. 16 Loader with Additional Rails for Loading Second Tier

connected at their delivery ends by a cross-shaft and at their receiving ends by a rail to which the electric hoist is hooked. Four barrels are run on the horizontal part of the loader, Fig. 15, and the

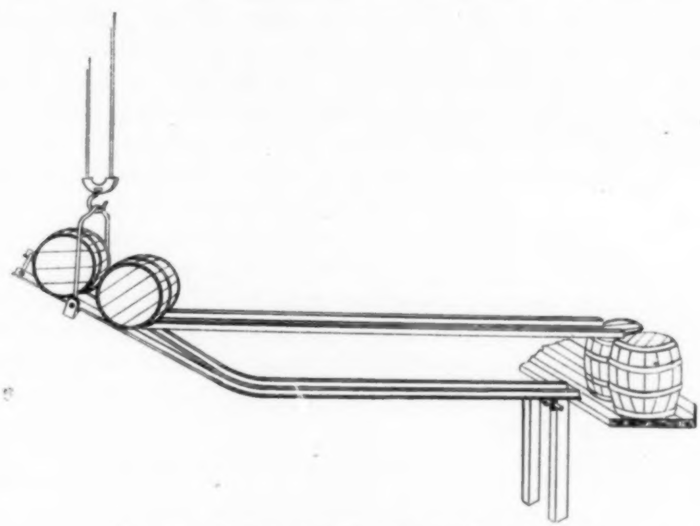

Fig. 17 Delivering Barrels to Second Tier

hoist then raises the end of the loader as in the general view, Fig. 14, until the barrels roll into the car. They are then up-ended until the first tier is completed. Then another pair of rails bent at one

end is attached to the first pair so that the free end of the second pair is high enough to deliver barrels on top of the first tier, Fig. 16 and 17. The hoister is simply made to lift higher in delivering the second tier. This hoister is easily moved from door to door of the warehouse, and the electric hoist overhead is easily traversed from place to place as needed.

40 It has been found much cheaper to load barrels into cars by means of this device than to roll the barrels for the first tier from the loading platform of an elevated warehouse into the car and then lift the barrels for the second tier by hand, and this machine makes it practicable to put the warehouse directly on the ground, thereby saving the expense of building an elevated warehouse floor.

41 Neither the reciprocating conveyor previously described nor the loading device are patented, and anyone may make them.

DISCUSSION

THE CONVEYING OF MATERIALS

HOISTING AND CONVEYING MACHINERY

By G. E. Titcomb, Published in June Proceedings

The Author To Mr. Pattison, and others, the author would say that dealing with the subject from the standpoint of personal experience, he obviously had not the data essential to a general report, and could merely recognize the art practiced by others.

2 Mr. Miller's outline of the usage possible to cableways is accepted as authoritative, though our practice rarely calls for the employment of a device with long free spans in transmission of loads. Mr. Pattison directs our attention to the performance of a number of machines at various points, and on the whole his facts are indorsed by references of the author concerning the different types of machinery employed. A point must be made of the apparent discrepancy in noting the importance of anthracite coal-handling machinery: a natural consequence of the greater prominence resulting from the early attention to the employment of mechanical means, and of the special type of successful apparatus inaugurated.

3 Our summary of the methods now in vogue for taking care of the immense tonnage of bituminous coal may be considered a sufficiently clear indication of the ability brought to bear in devising ways and means to handle it with expedition and economy. The available statistics will eventually serve as cumulative evidence of the progress following intelligent and systematic effort to perfect facilities.

CONTINUOUS CONVEYING OF MATERIALS

By S. B. Peck, Published in June Proceedings

The Author The subject of belt conveyors seems to have been pretty thoroughly handled. I regret that some of the numerous other successful types of conveyors have not elicited fuller discussion.

2 I agree with Mr. Piez, particularly as to the size of the pulleys and the location of the driving point, believing that the Transactions of this Society should show the best practice rather than what is occasionally expedient or permissible, and should even anticipate as far as possible the good practice of the future. The type of roller support shown in the lower half of Fig. 9, which troughs the belt but slightly and is supported by shafts runnning in pivoted chain-oiling bearings, has every advantage in its favor, though it requires a little wider belt and therefore greater first cost. I believe general experience to show that this objection disappears as soon as the real merit of a device is recognized, and I confidently expect to see this type of roller support very largely supersede the other forms in the next few years.

3 Mr. Messiter asks, following the same line of thought, why use a troughed belt at all: to which I would say that the slight troughing by the roller above referred to gives a practical increase in the carrying capacity of the belt much greater than might be supposed, the slight turning up of the edges checking the tendency of the material to spread laterally and dribble off the edge of the belt.

4 Mr. Bennett has criticised the four roll idler where a deep trough is required, shown in Fig. 9, on the ground that a central horizontal idler is necessary to make the belt run true and prevent a crease in the center of the belt. My experience with a large number of the four roll installations has not shown that either of these objections exists, at least with a belt of uniform structure.

5 I believe this type of belt least liable to localized bending, and having the strains caused by tension uniformly distributed, it has the least tendency to the separation of the plies so fatal to the life of a belt.

6 An advantage is claimed for the belt referred to as the "Robins patent," in the added thickness of rubber cushion in the center, due to the omission of some of the plies. I had occasion recently to examine an installation consisting of a large number of conveyors with belts of this type, supported on three roll idlers, with sides inclined about 35 deg. All these belts, in service for some time, were nearly worn out on the carrying side above the inclined side rollers, due presumably to the impact of the material at this point, while there was still a cushion of rubber in the center $\frac{1}{8}$ in. thick or more, from which obviously no benefit would ever be received. The natural conclusion was that the distribution of this rubber over the entire belt would have prolonged its life.

7 Professor Carpenter brings out very clearly in his Par. 3 the limitations of the belt conveyor for cement work, also speaking of the extended use of the screw conveyor, and some of the limitations to which I had also referred. The type of conveyor, however, which seems to be largely superseding both of these in the cement mills, is the pivoted overlapping bucket carrier which I show in Fig. 16. Its somewhat greater initial cost has perhaps prevented its more general adoption earlier, but its advantages, judging from the large number installed in the most recent cement plants, seem to be now quite generally recognized. This conveyor is perhaps the most reliable, and least subject to derangement, and it is equally adapted to fine and dusty or coarsely broken and gritty materials as well as to materials at a very high temperature; and it combines in the same machine the ability to convey and elevate. Both Professor Carpenter and Mr. Tomlinson have advocated the use of cars in cement mills, and after all, this carrier amounts to an endless train of small cars. Mr. Tomlinson offers the criticism, in his Par. 18, that these carriers are excessively heavy for the load, which I think is hardly borne out by

Size Feet	Weight per ft. empty Pounds	Capacity per ft. material 90 lb. per cu. ft. Pounds
24 by 18	70	75
24 by 24	75	100
24 by 30	80	125
24 by 36	85	150
30 by 36	115	180

the facts. The following are the weights per running foot of some of the sizes in more common use, together with the amount of material handled per running foot.

8 Comparison with the weight of ordinary industrial cars, or even freight cars, will show in favor of the conveyor, which, particularly in the larger sizes, weighs considerably less than the material handled. As to efficiency, by which I take it Mr. Tomlinson means the power necessary to operate, comparison with either type of car shows about the same advantage in favor of the conveyor.

9 I also want to take exception to the statement made by Mr. Tomlinson in Par. 15, that the pivoted bucket carrier cannot handle heated material. Carriers of this class are in very successful use in both cement and chemical works, handling both finely ground and coarsely broken material at nearly white heat. Mr. E. S. Fickes,

who has contributed a very interesting discussion on the subject of conveyors at this meeting, I think will bear testimony to this statement from personal experience.

10 A point not brought out by my paper is the advantage of chains of long pitch—18 to 24 in. and upwards. These, by their fewer joints or articulations, reduce the weight and cost of the conveyors and their elongation from wear. The cost of lubrication and repairs is also correspondingly reduced, and usually chains of long pitch afford better opportunity for the secure attachment of slats, pans or buckets. Their extended use has been made possible by what is commonly designated as an equalizing gear. As the sprocket wheels are polygonal in form, with usually six to ten sides, there is considerable variation in the lengths of the controlling radii, varying the chain speed and causing a jerky motion. The pitch circle of the equalizing gear wheel has a varying diameter, or a number of lobes corresponding to the number of sides of the sprocket wheel, and the pinion is correspondingly eccentric. The regularly varying speed ratio therefore exactly counteracts the speed variations that the differing diameters of the sprocket wheel would cause. This device is the invention of Mr. James M. Dodge, a well-known member and past president of this Society, to whose enthusiasm, fertility of mechanical suggestion and keen appreciation of commercial utility, the development of the conveying art is largely due.

CONVEYING MACHINERY IN A CEMENT PLANT

By C. J. Tomlinson, Published in June Proceedings

The Author I wish to correct the impression given by my paper, in regard to the relative proportion of use of belt conveyors and screw conveyors. As Professor Carpenter states, the screw conveyor is largely used in this work. It is a device that can be readily installed where the head room is restricted, and its large use is more the result of an effort to economize in the cost of plant erection than of the superior advantages of the device in operation.

2 If a belt conveyor is driven at comparatively slow speeds, about 200 to 250 ft. per min., much of its objectionable dust can be avoided. The additional cost of the wider belt required should not outweigh the advantages it has in operation over the less expensive screw and casing.

3 Mr. J. McGeorge asks the angle at which cement will flow. Cement will flow into a bin, and settle, at an angle of about 10 deg.

from the horizontal; after it has settled and the air has escaped, it will stand in the bin at about the same angle from the vertical. This angle of repose is variable, as the cement falls in miniature land slides when being drawn, and in the process of one of these slides will deliver through a hose. I have measured the angle in a number of bins and found it varying from 64 to 60 deg. from the horizontal, and at the latter angle it is very stable. A trough from a grinding machine will operate at an angle of 34½ deg. with free delivery at all times, but cannot be depended upon to start itself if the flow is shut off at the lower end.

4 In a dusty location this material settles on beams or ledges very like a heavy snow, clinging together with an apparent angle of repose of 75 deg. This peculiarity has caused trouble in belt conveyor tripper boxes, because of the tendency of detached particles to lodge and cone up about the heavy stream, preventing its free discharge. A box giving good satisfaction with a material having an angle of repose of 45 deg. will often give trouble with cement.

5 The phrase "angle of repose" is somewhat misleading, as materials often have one angle of flow through a smooth spout, another at which they will flow over themselves, and another at which they will stand when being drawn from a thoroughly settled storage. These angles all affect the capacity and arrangement of conveyors, bins and storage yards.

6 In Mr. Peck's closure several points are raised, which seem to require a reply.

7 An 18 by 24 in. pivoted bucket conveyor, with a capacity of 75 lb. per ft. and operating at a speed of 50 ft. per min., will handle the raw material for a 5000 bbl. plant and the clinker for a 7000 bbl. plant. For this reason this form of conveyor in the larger sizes is little used in cement plant work. The mechanical efficiency of a simple type of car may be increased by increasing its cubical contents, but an arrangement that limits the use of these cars to a continuous chain also limits this increase by causing the capacity of the chain to become so great as not to be applicable to the average condition.

8 Large bins and intermittent service, or a very slow speed of travel and a correspondingly large conveyor, are a possible recourse, but serve to emphasize the limitations of this arrangement. The average pivoted bucket conveyor has a pair of carrying wheels located above the center of gravity of the bucket and within 6 in. of its surface. When handling a highly heated material the problem of retaining a lubricant in these journals is a difficult one.

9 The application of a grease box and pad, so successful in railway practice, is prevented by the fact that the entire car is revolved as it passes around the various sprockets. Again, their large number precludes the adoption of any but the simplest oiling devices, and also prevents more than a minimum of individual attention.

10 In cement plant work, these conveyors are in many cases being operated without any attempt at lubrication. Compression grease cups are used almost exclusively on conveyors in this industry. The heavy grease is a good lubricant, with the slow speeds, and is also not so liable to wash dust particles into and along the journal. Its movement is a slow one away from the cup and toward the open end or ends, where it forms a ring that very effectively prevents the dirt from entering.

THE BY-PRODUCT COKE OVEN

By W. H. Blauvelt, Published in March Proceedings

The Author In considering the use of coke oven gas for gas engines the two points usually considered, aside from the heat value of the gas, are the hydrogen and sulphur contents. In a gas in which the nitrogen is properly controlled the hydrogen may vary from 40 to 55 per cent. The higher percentages of hydrogen in coke oven gas, compared with other gases, were formerly thought a serious objection. This has been overcome, as Mr. Bibbins and Dr. Fernald have stated. From the reports of some German engineers I find that they are able to prevent pre-ignition entirely in their practice by varying the compression in inverse proportion to the value of the gas mixture. A proper control of the admission of air and gas by the governor, so that the largest charge and weakest mixture are introduced when running under light loads, and the smaller charge and more powerful mixture under heavy loads, prevents injurious pre-ignitions and produces an equally inflammable mixture and uniform explosion. By proper care on these points some of the German plants have operated on coke oven gas for periods of four months without cleaning or stopping the engines.

2 The sulphur in coke oven gas exists in two forms, namely hydrogen sulphid and carbon bi-sulphid. The former may be readily removed by the ordinary purification process, but the latter cannot be removed by ordinary methods. Fortunately it exists in much the smaller proportion. Of course the amount of sulphur in the gas depends upon the coal from which it is made. The stipulations of the builders of the Lebanon plant, referred to by Mr. Bibbins, provided for a gas very low in sulphur. The ordinary specifications for purified illuminating gas stipulate a maximum of 20 gr. of sulphur compounds per 100 cu. ft., but this is of course a thoroughly purified gas. Coke oven gas made from coals suitable for metallurgical purposes contains before purification from 150 to 400 gr. per 100 cu. ft. 660 gr. per 100 cu. ft. equals 1 per cent by volume. Good German gas engine practice does not regard 0.2 per cent of sulphur as harmful, and does not purify the gas even when the percentages run higher.

They consider that copious lubrication of the parts exposed to the gas after combustion prevents any harm. If the large percentages of sulphur mentioned by Prof. Fernald in his St. Louis experience can be used without harm by the simple expedient of keeping the parts warm to prevent condensation, we may soon hope to see the sulphur question removed from consideration, and I think we may look forward with some confidence to the absence of apparatus for sulphur purification in a gas engine plant using coke oven gas.

3 In the consideration of coke oven gas for power purposes, the questions of supply and cost are of course essential. Perhaps these points may be made clearer by a brief consideration of the by-product oven operation. A by-product coke oven plant is so called because originally coke was the only product from a coke oven, and when by the improvement of the oven other products were saved, they were called by-products. At most plants coke is still the primary product, and especially where metallurgical coke is made the recovery of by-products is not allowed to injure the production of the best possible coke. In a retort oven plant, however, the coal is distilled for the purpose of producing several products, which may include coke, tar, ammonia, benzol, cyanides, gas, and perhaps others, any one of which may be the primary product, and all the others by-products. In the distillation of coal in a gas works, for instance, the gas retort takes the place of the oven and the primary product is gas, and the coke, tar, ammonia, etc., are by-products. In the large plant of by-product coke ovens at Everett, Mass., it might be correctly said that gas is the primary product, and the coke, tar, and ammonia the by-products, since the gas is used to supply illuminating gas to a large number of consumers and is an important part of the gas supply of that vicinity, while the coke, to a considerable extent, is sold as domestic fuel and in whatever quantity may be produced in furnishing the necessary supply of gas.

4 In undertaking the installation of a by-product coke oven plant, the owner must consider the operation as a whole. He has certain products to dispose of in the available market, and he must make his contracts and arrange his operation to meet the demand and the prices obtainable. If he has contracted to deliver a certain product at the maximum rate of production, it may become necessary to produce more of some other product than can be disposed of to the best advantage. This would result in loss unless he were able to modify his operation, perhaps by using another coal, or by some improvement in process, so as to effect a re-adjustment of relations

between the several products. The prospective owner of a plant considers fully the value he may expect from each of the products of the operation in connection with the cost of production, and the so-called "by-products" are no longer uncertain in quantity and value, and treated as a secondary consideration, though it may have been so to some extent in the earliest days of the by-product oven.

5 Of course the application of these statements to the use of coke oven gas in gas engines for power plants is that the operator of an oven plant contracting to deliver a certain amount of gas to a power plant would expect to live up to his contract to the same extent as if he had agreed to deliver a given quantity of tar, ammonia, or coke.

6 In order to guard against accidents beyond the control of the oven manager, and insure a continuous operation of the power plant, it might be advantageous to install a producer plant of sufficient capacity to operate the gas engine. As Mr. Bibbins has intimated in this discussion, the cost of such insurance would not be prohibitive. Or the producer plant may be installed at the coke ovens and the gas used to supplement the portion of the oven gas ordinarily consumed in heating the ovens. In practice the operation of the modern by-product coke oven plant has not been found subject to sudden or great fluctuations, and its products may be relied upon as fully as those from any manufacturing plant.

A RATIONAL METHOD OF CHECKING CONICAL PISTONS FOR STRESS

By Prof. George H. Shepard, Published in February Proceedings

The Author Mr. Nusim's discussion shows that a conical piston is somewhat stronger than the stress would indicate, when calculated as explained in my paper. Mr. Nusim does not attempt any quantitative evaluation of this additional strength; but the stresses shown by my method for actual pistons in successful use (See Table) render it probable that the method gives a fairly close approximation to the true value of the stress. Mr. Nusim shows that a designer would at least be on the safe side in using the method. The most that the author would claim is that it gives the designer a fairly convenient means of assuring himself of the safety of any conical piston, without being obliged to rely upon empirical methods.

ECONOMY TESTS OF HIGH SPEED ENGINES

By Messrs. Dean and Wood, Published in June Proceedings

The Authors There is very little to be said in closing the discussion, which is very interesting. Of course it is to be regretted that more and longer tests could not have been made. Some of the tests that have been mentioned in the discussion have been made after the engines were more or less repaired, and therefore do not come within the scope of the paper, which was to state results from several engines just as they were found.

2 It is to be regretted that Mr. Barrus has not submitted some of the results which he must have obtained in his extensive experience. Mr. Barrus regrets that no tests were made of engines with single piston valves with flexible rings. I am under the impression that the piston valve engines tested by Mr. Wood are of this class.

3 Many of the matters discussed, while of great interest, are scarcely relevant, and therefore will not be considered by me.

COMPARISON OF SCREW THREAD STANDARDS

By Amasa Trowbridge, Published in June Proceedings

The Author The proposition of Mr. Burlingame to establish a new standard thread does not appear attractive. Actually it matters very little whether a single formula is used to cover the range of threads or more than one. For some years the great majority of manufacturing concerns have been using the U. S. Standard thread for most of their work. To introduce a new standard to replace the old would cause a great deal of confusion and expense. The best solution of the matter seems to be the adoption of an entirely separate thread for sizes $\frac{1}{4}$ in. in diameter and over, called the U. S. Fine thread. This could be made enough finer than the present standard to meet the demands of the automobile manufacturers and others who cannot use that, and yet be coarse enough to serve for the machine-tool builders.

2 In view of the action taken by the Society in adopting the motion of Mr. Halsey, that a committee be appointed to consider the question of a standard for fine threads, it seems desirable to leave to that committee the consideration of the exact standard to be adopted.

NEW BOOKS

Mechanics of Engineering. By Irving P. Church, C.E. *John Wiley & Sons, New York*, 1908, Revised, illustrated. 8vo, cloth, 880 pp., $6.

Contents, by chapter headings: Part I—Statics of a Material Point; Parallel Forces and the Centre of Gravity; Statics of a Rigid Body; Statics of Flexible Cords. Part II—Rectilinear Motion of a Material Point; Virtual Velocities; Curvilinear Motion of a Material Point; Moment of Inertia; Kinetics of a Rigid Body; Work, Energy, and Power; Friction. Part III—Elementary Stresses and Strains; Torsion; Flexure of Homogeneous Prisms Under Perpendicular Forces in One Plane; Flexure of Reinforced Concrete Beams; Flexure; Columns and Hooks; Oblique Loads; Linear Arches (of Blockwork); Elements of Graphical Statics; Graphical Statics of Vertical Forces; Right Arches of Masonry; Arch-Ribs; Flexure of Beams, Simple and Continuous, Geometrical Treatment; Thick Hollow Cylinders and Spheres. Part IV—Definitions; Fluid Pressure; Hydrostatics Begun; Pressure of Liquids in Tanks and Reservoirs; Earth Pressure and Retaining Walls; Immersion and Flotation; Gaseous Fluids; Hydrokinetics Begun. Steady Flow of Liquids Through Pipes and Orifices; Steady Flow of Water in Open Channels; Kinetics of Gaseous Fluids; Impulse and Resistance of Fluids.

This is a revised edition partly rewritten and is the fifteenth thousand of Professor Church's work which has become so familiar to students and engineers. The treatise is characterized by rigid demonstrations illustrated by the clear and simple sketches which the author has a special faculty of making to illustrate the fundamental principles that he wishes to impress upon his students. The chapter on Continuous Girders by Graphics has been omitted, and much of the matter upon columns and beams has been rewritten and rearranged with the introduction of the more modern formulæ for columns, which include the problem of eccentric loading. There is an entirely new chapter on Flexure of Reinforced Concrete Beams and two others on the flexure of beams treated by a geometrical method; also one on the stresses in thick hollow cylinders and spheres, with matter on the strength of plates. There have been extensive additions, also, to the chapters on hydraulics and the mechanics of gases, especially on the subjects of weirs, meters, the pitot tube, and manometers.

Elementay Dynamics. By Prof. Ervin S. Ferry. *The Macmillan Company, New York*, 1908. Illustrated. 8vo, cloth, 182 pp.

Contents, by chapter headings: Fundamental Notions; Composition and Resolution of Forces; Friction Between Solids; The Motion of a Body Under the Action of Zero Force; The Motion of a Body Under the Action of a Constant Force; The Motion of a Body Under the Action of a Constant Torque; Energy; Statics of Fluids; Properties of Matter; The Motion of a Body Under the Action of a Variable Force.

The list of contents indicates the scope of this little treatise, which was written for students of Purdue University. In preparing this work the author has aimed to give accurate definitions of technical terms; to base his demonstrations by a few fundamental propositions underlying the subject of dynamics; to use concise and accurate methods of demonstration; and to verify the laws deduced by illustra-

tions from applications which are familiar. Numerous examples are given for solution by the student.

Concrete System. By Frank B. Gilbreth. *Engineering News Publishing Co., New York*, 1908. Illustrated. 8 by 11, leather, 182 pp.

Contents, by chapter headings: Part I—General Outlines of the Concrete System; General Rules; Forms; Reinforcement; Mixing; Transportation; Concreting; Testing; Finishing; Cast Stone; Making, Jetting, and Driving Corrugated Concrete Piles; Directions for Making Waterproof Cellars; Fire Tests of Concrete Constructions. Part II—Progress Photographs of Successful Concrete Work; The Largest Reinforced-Concrete Office Building in New York City; A Reinforced-Concrete Power Station in Seattle, Washington; A Reinforced Concrete Power Station in San Francisco, California.

This volume is primarily a printed note book, profusely illustrated. It contains a printed set of instructions gathered and developed by Mr. Gilbreth and issued to his employees as a code of rules for use in the field in carrying out his construction work. It assumes at the start a familiarity with concrete construction. The rules represent a gradual accumulation of information as a result of experience in the field. When an order was issued or a caution given, or a method fixed as a standard, then a memorandum was made which eventually found its way into the rules. As far as possible the rules are illustrated by engravings made from photographs showing the actual processes. They are supplemented by results and illustrations of fire tests on concrete construction; by data and illustrations of actual concrete construction, principally upon buildings; and folding plates giving working drawing of girders, floors, columns and other details.

Road Preservation and Dust Prevention, By William Pierson Judson. *The Engineering News Publishing Co., New York*, 1908. 3d edition, revised and enlarged. Illustrated. 8vo, cloth, 146 pp., $2.

Contents, by chapter headings: Road Dust; Moisture; Oil Emulsions; Oils; Coal-Tar Preparations; Tar-Spraying Machines; Tar-Macadam; Rock-Asphalt Macadam; Bitulithic Pavement.

This book is the direct outcome of the demand for better roads and the necessity for the preservation of the surface of roads since the automobile has come into extensive use. The destruction of the surface and the creation of dust where automobiles pass in large numbers have grown to be problems of great importance, which road builders have been striving to solve by different methods. The author shows what has been accomplished by engineers who have been working for the improvement of our highways and the abatement of the evils mentioned; and includes the conclusions reached by him after a study of the subject.

ACCESSIONS TO THE LIBRARY

BOOKS

USE OF THE NATIONAL FORESTS. U. S. Department of Agriculture Forest Service. *Washington, 1907.* 12mo, 42 p., cloth.

BINDERS FOR COAL BRIQUETS. Investigations made at the Fuel Testing Plant, St. Louis. By James E. Mills, U. S. Geological Survey, Bulletin 343. *Washington, 1908.* 8vo, 56 p., paper.

MODIFICATION OF ILLINOIS COAL BY LOW TEMPERATURE DISTILLATION. By S. W. Parr and C. K. Francis, University of Illinois Engineering Experiment Station, 1908. 8vo, 48 p.

STUDIES OF WATER STORAGE FOR FLOOD PREVENTION AND POWER DEVELOPMENT. State Water Supply Commission of New York. *Albany, 1908.* 8vo, 252 p., cloth.

THE SEWERAGE AND WATER BOARD OF NEW ORLEANS. 17th semi-annual report, June 30, 1908. 8vo, 23 p., paper.

CITY OF NEW YORK. Annual report of the Comptroller, year ended December 31, 1907. 8vo, 68 p., paper.

THE GEOLOGY AND ORE DEPOSITS OF THE CŒUR D'ALENE DISTRICT, IDAHO. By Fred. R. L. Ransome and Frank Cathcart Calkins, U.S. Geological Survey, Professional paper 62. *Washington, 1908.* 4to, 203 p., paper.

TRANSACTIONS

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS. *Transactions. Vol. 26, Parts 1 and 2, 1907.* 8vo, 1836 p., cloth.

INSTITUTION OF NAVAL ARCHITECTS. *Transactions. Vol. 50, 1908.* 4to, 330 p., 30 plates, cloth. *London, 1908.*

INSTITUTION ENGINEERS AND SHIPBUILDERS IN SCOTLAND. *Papers from Transactions. Vol. 51, 1907–1908.*

Electric Propulsion of Ships. By Henry A. Mavar. 8vo, 71 p.
Electrical Equipment of the Cunard Express Steamer Mauretania. By Wm. C. Martin. 8vo, 25 p., paper.

Reinforced Concrete and its Practical Application. By M. Kahn. 8vo, 35 p., paper.

Laying Out and Use of Calculating Charts. By T. B. Morley. 8vo, 15 p., paper.

Malleable Cast Iron. By W. H. Hatfield. 8vo, 24 p., paper.

Notes on Electric Driving. By Theo. Parsons. 8vo, 19 p., paper.

CATALOGUES AND CIRCULARS

Anderson Evans Co. *Chicago.* Ore and Coal Hauling Plants. Grab Buckets.

Carnegie Library. *Pittsburg, 1908.* 2 vol., second series, 1902–1906. 8vo, 2019 p., cloth.

The Coe Brass Mfg. Co., *Torrington and Ansonia, Conn., 1906.*

General Electric Co., Schenectady, N. Y. Railway Converter Sub-stations.

General Electric Transformers. Type H, Bulletin 4535.

Westinghouse Elec. and Mfg. Co. *Pittsburg, Pa.* Detail and Supply Department. Circulars.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

027 Isthmian Canal Commission, No. 1—Citizen of the United States; graduate of electrical or mechanical course from a technical college or university; at least thirty years of age, to have had two years in construction work either shop or field, and one year in responsible charge; two years drafting, one year of practical design; must produce drawings which exhibit the character of work done. Desired that he be a member of one of the Engineering Societies. Salary $225 per month.

028 No. 2—Essentially same as requirements for 027; at least twenty-eight years of age; and have had two years of construction work, either shop or field in electrical, mechanical, or civil engineering; two years' drafting; must produce drawings of work. Experience in design of heavy machinery, shop experience of this class particularly desired; present a certificate of qualifications from the various employers. Salary $200 per month.

029 Electrical contracting business desires young engineer with some actual experience including the wiring of buildings and the installation of motors, lights, etc. Also a man of same general character with experience in gas fitting and plumbing work. Location Texas.

030 Young man as manager of sales, office and shops in young and growing concern manufacturing several engineering specialties. Technical education preferred. Applicant must have initiative, be aggressive, experienced and up to date as to system, follow-up method, advertising, etc. Salary $40 per week, increase depending only on results. State experience, age, etc., and give references.

031 Man to take charge of drafting room, familiar with the general run of mechanical and electrical engineering work, designing special machinery and estimating on electrical and some construction installations.

032 Technical graduate conversant with engine design and up-to-date practice. Salary $100 to $125 per month depending on the qualifications of the applicant.

MEN AVAILABLE

140 Mechanical Engineer (Stevens Inst.), professional experience, responsible. Solicits correspondence with graduate Architect of equal standing proposing to establish (location to be determined) for suburban architectural and contract work.

141 Practical Mechanical Engineer (Member), twenty years experience designing, manufacturing and selling. Specialty preliminary lay outs for power plants, foundries, conveying and special machinery. Established in New York. Wide acquaintance and selling experience. Would consider Eastern representative for manufacturer.

142 Mechanical engineer, college graduate, 15 years' practical experience in hoisting and conveying machinery, machine tools, pumps, gas manufacturing, steam shovels, railroad work, etc. New York preferred.

143 Member, broad experience in hydraulic work; has successively held positions of designer, chief-draftsman and assistant superintendent of one of the largest pump works in the United States, wants position; location immaterial.

144 Mechanical superintendent, works manager or similar position, wanted by a competent man with a thorough technical and practical training, up-to-date in the economical maintenance of labor and machinery and the generation and distribution of power; and successful in designing and introducing labor saving methods and appliances, tools, automatic machinery; excellent executive ability and capable of producing results.

145 Junior with railroad, general engineering and selling experience; technical graduate, 1901, in mechanical engineering, desires position as assistant to general manager of engineering corporation or similar work.

146 Mechanical engineer, college graduate, 15 years' practical experience in hoisting and conveying machinery, machine tools, pumps, gas manufacturing, steam shovels, railroad work, etc. New York preferred.

147 Junior, married, graduate mechanical engineer, experience in machine shop and as stationary engineer, light and water plant. Four years building, testing, erecting and operating horizontal steam turbines. Also general power house construction work. Desires position as chief engineer of large plant or assistant to superintendent. Central station and traction work preferred.

148 Associate Member; technical graduate, seven years' experience in the installation of all kinds of power plant apparatus, including steam turbines, gas engines, producers and mechanical stokers; shop and business experience; is open for a position as chief engineer of a large power plant or superintendent of construction for manufacturing concern.

149 Associate, age 31, desires to make a change. Twelve years varied drawing room experience, including checking and charge of men. Prefers work on heavy machinery and furnaces, rolling, steel and tube mills. Location preferably within 100 miles of New York or Philadelphia.

150 Superintendent and Manager open to engagement. Well up on machine shop and foundry work. Technical graduate. Practical. Good executive. Successful.

151 Graduate mechanical engineer, four years' experience testing, demonstrating and reporting on steam, gas, gasolene, engines and automobiles, desires position in sales department of automobile or marine engine concern. New York or vicinity preferred.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ABBOTT, Frederick Bancroft (1904), 490 7th St., Brooklyn, N. Y.

BACON, John Lord (Junior, 1899), 1020 Montrose Ave., South Pasadena, Cal.

BARNABY, Charles W. (1884), 309 Broadway, New York, N. Y.

BASINGER, James Garnett (1907), 523 W. 121st St., New York, N. Y.

BAYLE, Emile J. (1907), Genl. Engr., American Beet Sugar Co., and *for mail*, 1530 16th St., Denver, Colo.

BERTSCH, John Charles (1901), Cons. Engr., 228 Brown-Randolph Bldg., Atlanta, Ga.

BIGELOW, Charles H. (1904), Insp. Engr., L. B. Stillwell on Hudson Cos. Power Sta., and *for mail*, 237 Duncan Ave., Jersey City, N. J.

BIXLER, Harry Zera (1907), 224 W. Rayen Ave., Youngstown, O.

BODWELL, Howard L. (1907), Asst. Dist. M.M., Am. Sheet and Tin Plate Co., Vandergrift, Pa.

BUCK, Irwin (Junior, 1907), Mech. Engr., U. S. Industrial Alcohol Co., 100 William St., New York, N. Y.

CARPENTER, Harold Eugene (1908), Supt. of Constr., Astoria Light, Heat and Power Co., Astoria, and *for mail*, The Courtland, 1219 Madison Ave., New York, N. Y.

COES, Harold V. O. (Junior, 1907), Mech. Engr., N. Y. Edison Co., and *for mail* 519 W. 124th St., New York, N. Y.

COLE, Dwight S. (1903), 159 S. Lafayette St., Grand Rapids, Mich.

COLE, Francis J. (1888), Mech. Engr., Am. Loco. Co., Schenectady, N. Y.

CUSHMAN, Arthur Wesley (Junior, 1905), Div. Supt., Swift & Co., Chicago, Ill.

DOELLING, Louis Chas. (1906), V. P. and Genl. Supt., De La Vergne Mch. Co., foot E. 138th St., New York, N. Y.

EBERHARDT, Elmer Gould (1904; Associate, 1907), V. P., Newark Gear Cutting Mch. Co., 66–68 Union St., and *for mail*, 113 Orchard St., Newark, N. J.

EBERHARDT, Frank Edward (Junior, 1907), Treas., Newark Gear Cutting Mch. Co., 66 Union St., Newark, N. J.

EBERHARDT, Henry J. (1902; Associate, 1906), Secy., Newark Gear Cutting Mch. Co., 66 Union St., Newark, and 328 Lyons Ave., Irvington, N. J.

FOLGER-OSBORNE, G. F. (1903), care of Messrs. Cox & Co., Bankers, Fort Bombay, British India.

FOSTER, Horatio A. (1895), Tribune Bldg., 154 Nassau St., New York, N. Y.

GOENTNER, William B. (Junior, 1905), Willow Grove, Montgomery Co., Pa.

GILLIS, H. A. (1888), Mgr., 1901–1904; Fowler, Hardesty & Gillis, Cons. Engrs., Home Life Bldg., Washington, D. C.

GORDON, Rea M. (Junior, 1902), Asst. Engr. of Tests, Solvay Process Co., and *for mail*, 533 S. Salina St., Syracuse, N. Y.

HANSON, Walter S. (Associate, 1902), Clinton, Okla.

HANSON, Augustus (1886), Nevada California Power Co., Tonopah, Nev.

HUTTON, Frederick R. (1880), Secy., 1883–1906; Pres., 1907; Life Member; Emeritus Prof. Mech. Engrg., Columbia Univ., and 29 W. 39th St., and *for mail*, 257 W. 86th St., New York, N. Y.

INGHAM, Howard M. (1907), Mgr., Bliss-Griffiths Constr. Co., 225 Fifth Ave., New York, N. Y., and *for mail*, 76 Dwight Pl., Englewood, N. J.

JUNGHANS, Edward K. (1908), Supt. and Ch. Engr., The Porvenir Sugar Co., Yngenio Porvenir, San Pedro de Macoris, Santo Domingo, W. I.

KELMAN, John H. (1904), 194 Lefferts Pl., Brooklyn, N. Y.

KINKEAD, James A. (Associate, 1903), Mgr. of Sales, The Parkesburg Iron Co., 2601 Singer Bldg., New York, N. Y.

KREBS, A. Sonnin (1901; Associate, 1905), Mech. Engr., 1327 N. Nevada Ave., Colo. Springs, Colo.

LANGLOTZ, Robert (1894; Associate, 1904), 78 Delevan St., and *for mail*, 786 President St., Brooklyn, N. Y.

LATTA, M. Nisbet (Junior, 1902), 106 Jackson St., Seattle, Wash.

LEACH, William H., Jr. (1905), Mech. Engr., Union Metallic Cartridge Co., and 141 Lenox Ave., Bridgeport, Conn.

LEPPER, John G. (1902), E. P. Linch Co., Real Estate Trust Bldg., Broad and Chestnut Sts., Philadelphia, Pa.

LINCH, Edward P. (1902), Real Estate Trust Bldg., Philadelphia, Pa.

LODETTI, Frank Emil (Junior, 1902), Faido Sta., Switzerland.

LONG, Jeremiah C. (1905), Boston Woven Hose and Rubber Co., Cambridgeport, Mass.

LYMAN, Elihu Root (Junior, 1904), Mech. Engr., U. S. Heater Co., Detroit, Mich.

MARQUIS, Frank W. (Junior, 1908), 205 W. Hill St., Champaign, Ill.

METZ, Walter R. (Junior, 1902), Leading Draftsman, U. S. Navy Yard, and *for mail*, 211 A St. N. E., Washington, D. C.

MOYER, James A. (1907), Asst. Prof. of Mech. Engrg., University of Mich., Ann Arbor, Mich., and Norristown, Pa.

MURRIE, John L. (Junior, 1905), Mech. Engr., Public Service Com., 1st Dist., Tribune Bldg., and *for mail*, 65 W. 94th St., New York, N. Y.

NEWTON, Peter Augustin (1905), Asst. Genl. Supt., Illinois Steel Co., South Wks., S. Chicago, and *for mail*, 5006 Madison Ave., 3d Flat, Chicago, Ill.

OSTRANDER, Allen Edward (Associate, 1905), 33 18th Ave., Paterson, N. J.

PENTZ, Albert D. (1891) 31 Central Ave., Tompkinsville, Staten Island, N. Y.

PRESCOTT, James A. (Junior, 1897), 321 Lincoln Trust Bldg., St. Louis, Mo.

RICHARDS, Charles R. (1890), Cooper Union, New York, N. Y.

SCHAKEL, Jacob Daniel (Associate, 1907), Otis Elevator Co., Cor. 12th and Samson Sts., Philadelphia, Pa.

SEARING, Hudson R. (1893), 204 W. 132d St., New York, N. Y.

SMEAD, William H. (Junior, 1906), Mech. Engr., Proximity Mfg. Co.'s Mills, Greensboro, N. C.

SOWDEN, Parkin T. (Junior, 1908), Supt., Standard Silver Co., and 80 College St., Toronto, Can.

SPURLING, O. C. (1907), Asst. Plant Engr. and Factory Engr., Western Elec. Co., Chicago, and *for mail*, 312 S. 5th Ave., La Grange, Ill.
STOTT, Henry G. (1902), Mgr. 1907–1909; Supt. M. P., Interborough Rapid Transit Co., New York, and *for mail*, Rochelle Heights, New Rochelle, N. Y.
SULLIVAN, Lucien N. (1903), 1502 Meridian Pl. N. W., Washington, D. C.
THOMAS, Edward G. (1890; 1907), Supt., Ariston Marble Co., 203 37th St., and *for mail*, 157 Congress St., Brooklyn, N. Y.
TUTTLE, Willard S. (1900), 227 W. Hortter St., Philadelphia, Pa.
WALLIS, Philip (1886), Hotel Roanoke, Roanoke, Va.

NEW MEMBERS

BROWN, Herman Elisha (1908), Alsen, N. Y.
BURGESS, Edward Wesley (Junior, 1908), Highland Court, Hartford, Conn.
BURTON, Isaac Francis (1908), Asst. Supt., Victor Talking Mch. Co., 5219 Walnut St., Philadelphia, Pa.
ELLIS, Weldon T. (Junior, 1908), Asst. in Mech. Engrg. Dept., N. C. College of Agriculture and Mech. Arts, West Raleigh, N. C.
HAYES, J. Howard (Junior, 1908), Salesman, Platt Iron Wks. Co., Boston, and *for mail*, 46 William St., Cambridge, Mass.
LAMBIE, James M. (Junior, 1908), 549 E. Chestnut St., Washington, Pa.
MARZOLI, Luigi (Junior, 1908), Supt. and Partner, Fratelli Marzoli & Co., Palazzolo s/Oglio, Province of Brescia, Italy.
NEWCOMB, Chas. L., Jr. (Associate, 1908), 206 Sheldon Bldg., San Francisco, Cal.
SMITH, S. H. (Associate, 1907), Supt., The North Melbourne Elec. Tramways and Lighting Co., Ltd., Mt. Alexander Road, Ascot Vale, Melbourne, Victoria, Australia.
TAYLOR, Cecil Hamelin (Associate, 1908), Engrg. Dept., E. R. Thomas Motor Co., Buffalo, N. Y.
WEBER, Herman Frederick (Junior, 1908), Mech. Draftsman, Westinghouse, Church Kerr & Co., and *for mail*, 815 E. 169th St., New York, N. Y.

ADVANCE IN GRADE

BARNES, Chas. B. (1905; 1908), Mech. Engr., Holabird & Roche, Architects, 1618 Monadnock Bldg., and *for mail*, 6045 Kimbark Ave., Chicago, Ill.

RESIGNATIONS

HEDENBERG, Wm. L.

COMING MEETINGS OF SOCIETIES

AMERICAN ELECTROCHEMICAL SOCIETY

October 30, College of the City of New York. Secy., Dr. J. W. Richards, South Bethlehem, Pa. Acting Secy., W. S. Landis.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

November 13, 33 W. 39th St., New York, 8 p. m. Secy., R. W. Pope. Paper: Electrical Heating, W. A. Hadaway, Jr.

AMERICAN GAS INSTITUTE

October 21–23, annual convention, 29 W. 39th St., New York. Secy., James W. Dunbar, New Albany, Ind. Papers: High Pressure Distribution, J. D. Von Maur; Benzol Enrichment, E. H. Earnshaw; Photometry of Gas, C. O. Bond; Physical Theory of Coal Carbonization, W. H. Fulweiler; Vertical Retorts, J. H. Taussig; Relative Merits of Wrought Iron and Steel Pipe, F. N. Speller; Progress on "A" Meters, W. J. Sevrill; Progress on Dipping Meters, W. A. Castor; Holder Cups and Tank Heating, C. J. Ramsburg; Better Gas Illumination, J. T. Litle.

AMERICAN RAILWAY ASSOCIATION

November 18, annual meeting, Chicago, Ill. Secy., W. F. Allen, 24 Park Pl., New York.

AMERICAN SOCIETY OF CIVIL ENGINEERS

November 4, New York. Secy., Chas. W. Hunt, 220 W. 57th St.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

November 10, 29 W. 39th St., New York, 8 p.m. December 1–4, annual meeting. Secy., Calvin W. Rice.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENTS

October 20–23, annual convention, Atlantic City, N. J. Secy., A. Prescott Folwell, Flatiron Building, New York.

ASSOCIATION OF RAILWAY SUPERINTENDENTS OF BRIDGES AND BUILDINGS

October 20–22, annual meeting, Arlington Hotel, Washington, D. C. Secy., S. F. Patterson, Concord, N. H. Papers: Water-proofing of Concrete Covered Steel Floors; Modern Equipment and Tools for Erection of Steel Bridges; Protection of Structures Against Effects of Electric Currents; Protection of Embankments from the Effects of High Water by Rip-rap or Otherwise; Experience in the Use of Gasolene Engines and Kerosene Engines or Combination of Same for Water Supply, Drawbridges, Etc.; Modern Dwelling Houses for Section Foremen and Section Men in Outlying Districts; Re-enforced Concrete Culverts and Short Span Bridges; Methods of Erecting Truss Bridges; Maintaining Traffic; No Traffic; Smoke Jacks for Engine Houses.

BLUE ROOM ENGINEERING SOCIETY

November 5, 29 W. 39th St., New York, 8 p.m. Secy., W. D. Sprague.

BOSTON SOCIETY OF CIVIL ENGINEERS
October 21, monthly meeting, Tremont Temple. Secy., S. E. Tinkham, 60 City Hall.

BROOKLYN ENGINEERS' CLUB
November 12, 197 Montague St. Secy., J. Strachan. Paper: Some Features of the Bridges of the Harlem River Branch, N. Y., N. H. and H. R. R., H. C. Keith.

CANADIAN RAILWAY CLUB
November 3, Montreal, Que. Secy., James Powell, Grand Trunk Railway.

CAR FOREMEN'S ASSOCIATION OF CHICAGO
November 9. Secy., Aaron Kline, 326 N. 50th St.

CENTRAL ASSOCIATION OF RAILROAD OFFICERS
November 2, Indianapolis, Ind. January 1, 1909, annual meeting, 257 Broadway. Secy., G. B. Staats, Care of Penna. Lines.

CENTRAL ASSOCIATION OF RAILROAD OFFICERS
November 9, Kansas City. Secy., J. H. Ashley, Gumbel Bldg.

CENTRAL ASSOCIATION OF RAILROAD OFFICERS
November 12, Toledo, O. Secy., H. M. Elliott.

CENTRAL RAILWAY AND ENGINEERING CLUB OF CANADA
October 20, Rossin House, Toronto, Ont. Secy., C. L. Worth, Room 409, Union Station. Paper: The Handling of Stores, A. Tory.

CENTRAL RAILWAY CLUB
November 13, Buffalo, N. Y., 2 p.m. Secy., H. D. Vought, 95 Liberty St., New York.

CLEVELAND ENGINEERING SOCIETY
November 10, monthly meeting, Caxton Building. Secy., Joe C. Beardsley.

COLORADO SCIENTIFIC SOCIETY
November 7, Denver. December 19, annual meeting. Secy., Dr. W. A. Johnston, 801 Symes Bldg.

EXPLORERS CLUB
November 6, 29 W. 39th St., New York, 8.30 p.m. Secy., H. C. Walsh.

ENGINEERS AND ARCHITECTS' CLUB OF LOUISVILLE, KENTUCKY
October 19, monthly meeting, 303 Norton Bldg. Secy., Pierce Butler.

ENGINEERING ASSOCIATION OF THE SOUTH
October 20, monthly meeting, Nashville Section, Carnegie Library Bldg. Section Secy., H. H. Trabue, Berry Block, Nashville.

ENGINEERING SOCIETY OF THE STATE UNIVERSITY OF IOWA
November 3, monthly meeting, Iowa City, Ia. Dean, Wm. G. Raymond.

ENGINEERS' CLUB OF BALTIMORE
November 7. Secy., R. K. Compton, City Hall.

ENGINEERS' CLUB OF CENTRAL PENNSYLVANIA
November 3, monthly meeting, Gilbert Bldg., Harrisburg. January 5, 1909, annual meeting. Secy., E. R. Dasher.

ENGINEERS' SOCIETY OF MILWAUKEE
November 11, monthly meeting. June 9, annual meeting. Secy., W. Fay Martin, 396 Bradford Ave.

ILLUMINATING ENGINEERING SOCIETY
November 12, 29 W. 39th St., New York, 8 p.m. Secy., P. S. Millar.

IOWA RAILWAY CLUB
November 13, Des Moines. Secy., W. B. Harrison, Union Sta.

LOUISIANA ENGINEERING SOCIETY
November 9, monthly meeting, 323 Hibernia Bldg., New Orleans. January 9, 1909, annual meeting, New Orleans. Secy., L. C. Datz, 323 Hibernia Bldg.

MASSACHUSETTS STREET RAILWAY ASSOCIATION
November 11, Boston. Secy., Charles S. Clark, 70 Kilby St.

MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK
October 28, 29 W. 39th St., 8:15 p.m. Secy., C. D. Pollock.

NATIONAL MACHINE TOOL BUILDERS' ASSOCIATION
October 20–21, annual convention, Hotel Imperial, New York. Secy., P. E. Montanus, Springfield, O.

NEW ENGLAND RAILROAD CLUB
November 10, monthly meeting, Boston, Mass. Secy., Geo. H. Frazier, 10 Oliver St., Boston.

NEW ENGLAND STREET RAILWAY CLUB
October 22, American House, Boston, Mass. March 25, 1909, annual meeting. Secy., John J. Lane, 12 Pearl St.

NEW ENGLAND WATER WORKS ASSOCIATION
November 11, regular meeting. Secy., Willard Kent, Tremont Temple, Boston, Mass.

NEW YORK SOCIETY OF ACCOUNTANTS AND BOOKKEEPERS
October 20, 27, November 3, 10, 17, 29 W. 39th St., 8 p.m. Secy., T. L. Woolhouse.

NEW YORK TELEPHONE SOCIETY
October 20, November 17, 29 W. 39th St., 8 p.m. Secy., T. H. Laurence.

NORTHERN RAILWAY CLUB
October 24, Commercial Club Rooms, Duluth, Minn. Secy., C. L. Kennedy.

NORTHWEST RAILWAY CLUB
November 10, St. Paul, Minn. Secy., T. W. Flannagan, Soo Line, Minneapolis, Minn.

PACIFIC NORTHWEST SOCIETY OF ENGINEERS
November 7, monthly meeting, Lowman Bldg., Seattle, Wash. Secy., Arthur H. Dimock, City Engineer's Office. Paper: Sluicing Operations on Topographers Hill, E. W. Commings.

PROVIDENCE ASSOCIATION OF MECHANICAL ENGINEERS
October 27, monthly meeting, 48 Snow St. June 22, 1909, annual meeting. Secy., T. M. Phetteplace.

PURDUE MECHANICAL ENGINEERING SOCIETY
October 28, November 11, Purdue University, Lafayette, Ind., 6:30 p.m. Secy., L. B. Miller.

RAILWAY CLUB OF PITTSBURGH
October 23, annual meeting, Monongahela House, 8 p.m. Secy., J. D. Conway, Gen. Office, P. & L. E. R. R.

RENSSELAER SOCIETY OF ENGINEERS
October 23, November 6, 257 Broadway, Troy, N. Y. Secy., R. S. Furber.

RICHMOND RAILWAY CLUB
November 9. Secy., F. O. Robinson, C. & O. Railway.

ROADMASTERS' AND MAINTENANCE OF WAY ASSOCIATION
November 10, Milwaukee, Wis. Secy., Walter E. Emery, Pekin Union Railway, Peoria, Ill.

ROAD AND TRACK SUPPLY ASSOCIATION
November 10-12, Milwaukee, Wis. Secy., John W. Reynolds, 160 Harrison St., Chicago, Ill.

ROCHESTER ENGINEERING SOCIETY
November 13, monthly meeting. Secy., John F. Skinner, 54 City Hall.

SHORT LINE RAILROAD ASSOCIATION
November 2, New York. Secy., Cromwell G. Macy, Jr., Nantucket Central Railroad, 257 Broadway.

ST. LOUIS RAILWAY CLUB
November 13, monthly meeting. Secy., B. W. Frauenthal.

TECHNICAL SOCIETY OF BROOKLYN
November 6, semi-monthly meeting, Arion Hall, Arion Place, Brooklyn, N. Y., 8:30 p. m. Pres., M. C. Budell, 20 Nassau St., New York

TECHNOLOGY CLUB OF SYRACUSE
November 10, monthly meeting, 502 The Bastable Blk. Secy., Geo. D. Babcock.

WASHINGTON SOCIETY OF ENGINEERS
October 20, Hubbard Memorial Hall, Washington, D. C., 8 p.m. Paper: Combustion, Paul M. Chamberlain.

WESTERN ELECTRIC CLUB
November 10, 29 W. 39th St., New York, 8 p.m. Secy., J. W. Dietz.

WESTERN RAILWAY CLUB
October 20, monthly meeting, Auditorium Hotel, Chicago, Ill., 8 p.m. Secy., Jos. W. Taylor, 390 Old Colony Bldg.

WESTERN SOCIETY OF ENGINEERS
October 21, November 4, bi-weekly meetings, 1737 Monadnock Blk., Chicago, Ill. January 5, 1909, annual meeting. Secy., J. H. Warder. Papers: October 21, Notes on Macadam Road Construction, A. N. Johnson; November 4, Retaining Walls.